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A limnological data profile was developed for each of the bodies of water sampled. A data processing procedure was used to establish the relationship between water quality data and algal cell density, chlorophyll a and productivity.

The algal assay procedure provided an indication of limiting nutrient, phosphorus, nitrogen, or both. By clustering all samples of similar nutrient limitation a basic nitrogen, phosphorus relationship emerged. When the ratio of soluble inorganic nitrogen to total soluble phosphorus was greater than 13 the waters were phosphorus limited, when the ratio was in the range of 9-12 both nutrients were limiting, and when the ratio was below 8 nitrogen was limiting.

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EVALUATION OF THE ALGAL ASSAY PROCEDURE

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A limnological data profile was developed for each of the bodies of water sampled. A data processing procedure was used to establish the relationship between water quality data and algal cell density, chlorophyll a and productivity.

The algal assay procedure provided an indication of limiting nutrient, phosphorus, nitrogen or both. By clustering all samples of similar nutrient limitation a basic nitrogen, phosphorus relationship emerged. When the ratio of soluble inorganic nitrogen to total soluble phosphorus was greater than 13 the waters were phosphorus limited when the ratio was in the range of 9-12, both nutrients were limiting, and when the ratio was below 8 nitrogen was limiting.

The quantity of algal biomass grown in autoclaved or filtered samples, without the addition of nutrient spikes provides an indication of the relative trophic or nutrient level of the particular body of water, the former a measure of total growth potential and the latter ambient growth potential.

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CONTENTS

		Page
Abstract		iii
Acknowledgements		iv
Figure		vi
List of Tables		vii
I	Introduction	1
II	Summary	2
III	Conclusions	3
IV	Recommendations	4
V	Experimental Plan	5
VI	Methods and Procedures	9
VII	Results and Discussion	12
VIII	References	50
IX	Appendix	52

FIGURE

Number		Page
1	Location and Nature of Surface Waters Sampled in North Carolina and Adjacent Areas	8

LIST OF TABLES

Number		Page
1	Surface Waters of North Carolina and Adjacent Areas Evaluated by Algal Assay	5
2	Physical, Chemical and Biological Parameters, All Lake Samples Used in Algal Assays, Mean Values Within Value Range of Indicated Parameter: Inorganic Nitrogen (NH_3+NO_2+NO_3) mg/m^3	14
3	Physical, Chemical and Biological Parameters, All Lake Samples Used in Algal Assays, Mean Values Within Value Range of Indicated Parameter: Total Nitrogen - mg/m^3	15
4	Physical, Chemical and Biological Parameters, All Lake Samples Used in Algal Assays, Mean Values Within Value Range of Indicated Parameter: Total Soluble-P - mg/m^3	16
5	Physical, Chemical and Biological Parameters, All Lake Samples Used in Algal Assays, Mean Values Within Value Range of Indicated Parameter: Total-P - mg/m^3	17
6	Physical, Chemical and Biological Parameters, All Lake Samples Used in Algal Assays, Mean Values Within Value Range of Indicated Parameter: Ratio TN/TP	18
7	Physical, Chemical and Biological Parameters, All Lake Samples Used in Algal Assays, Mean Values Within Value Range of Indicated Parameter: Cell Density No./ml	19
8	Physical, Chemical and Biological Parameters, All Lake Samples Used in Algal Assays, Mean Values Within Value Range of Indicated Parameter: Chlorophyll a Turner Units	21
9	Physical, Chemical and Biological Parameters, All Lake Samples Used in Algal Assays, Mean Values Within Value Range of Indicated Parameter: Productivity - $mgC/m^3/hr$	22
10	Growth of Selenastrum capricornutum in NAAM (14 Days, 24°C, 400 f.c.); Mean Values of Biomass and Unit Absorbance	23
11	Growth of Selenastrum capricornutum in Lake Samples, Controls and on Addition of Nutrient Spikes of Nitrogen and Phosphorus	25

LIST OF TABLES Continued

Number		Page
12	Growth Response of Selenastrum capricornutu in Lake Samples, Controls and on Addition of Nutrient Spikes of Nitrogen and Phosphorus	26
13	Growth Response of Selenastrum capricornutum in Lake Samples, Controls and on Addition of Nutrient Spikes of Nitrogen and Phosphorus	27
14	Growth Response of Selenastrum capricornutum in Lake Samples, Controls and on Addition of Nutrient Spikes of Nitrogen and Phosphorus	28
15	Growth Response of Selenastrum capricornutum in Lake Samples, Controls and on Addition of Nutrient Spikes of Nitrogen and Phosphorus	29
16	Growth Response of Selenastrum capricornutum in Lake Samples, Controls and on Addition of Nutrient Spikes of Nitrogen and Phosphorus	30
17	Growth Response of Selenastrum capricornutum in Lake Samples, Controls and on Addition of Nutrient Spikes of Nitrogen and Phosphorus	31
18	Growth Response of Selenastrum capricornutum in Lake Samples, Controls and on Addition of Nutrient Spikes of Nitrogen and Phosphorus	32
19	Growth Response of Selenastrum capricornutum in Lake Samples, Controls and on Addition of Nutrient Spikes of Nitrogen and Phosphorus	33
20	Growth Response of Selenastrum capricornutum in Lake Samples, Controls and on Addition of Nutrient Spikes of Nitrogen and Phosphorus	34
21	Growth Response of Selenastrum capricornutum in Lake Samples, Controls and on Addition of Nutrient Spikes of Nitrogen and Phosphorus	35
22	Correlations of Seeded Control Growth and Nutrient Concentrations Following Pre-Treatments	37
23	Correlations of Seeded Control Growth and Nutrient Concentrations Following Pre-Treatments	38

LIST OF TABLES Continued

Number		Page
24	Correlations of Seeded Control Growth and Nutrient Concentrations Following Pre-Treatments	39
25	Correlations of Seeded Control Growth and Nutrient Concentrations Following Pre-Treatments	40
26	Correlation of Growth in Non-Spiked Samples of Phosphorus Limited Waters, Autoclaved Pretreatment, with Sample Nutrients and Comparison to Original Lake Nutrient Concentrations	41
27	Correlation of Growth in Non-Spiked Samples of Phosphorus Limited Waters, Filtered Pretreatment, with Sample Nutrients and Comparison to Original Lake Nutrient Correlations	42
28	Correlation of Growth in Non-Spiked Samples of Nitrogen Limited Waters, Autoclaved Pretreatment, with Sample Nutrients and Comparison to Original Lake Nutrient Concentrations	43
29	Correlation of Growth in Non-Spiked Samples of Nitrogen Limited Waters Filtered Pretreatment, with Sample Nutrients and Comparison to Original Lake Nutrient Concentrations	44
30	Correlation of Growth in Non-Spiked Samples of Phosphorus & Nitrogen Limited Waters, Autoclaved Pretreatment, with Sample Nutrients and Comparison to Original Lake Nutrient Concentrations	45
31	Correlation of Growth in Non-Spiked Samples of Phosphorus & Nitrogen Limited Waters, Filtered Treatment, With Sample Nutrients and Comparison to Original Lake Nutrient Concentrations	46
32	Relationship of Control Growth, Seeded Senenastrum capricornutum in Autoclaved and Filtered Waters and Nutrient Levels of Original Raw Water	47
33	Nutrient Limitation of Algal Assayed Samples, Control Biomass and Original Lake Nutrient Quality	49

SECTION I

INTRODUCTION

The problem of man induced eutrophication in the United States has led to the development of bioassay procedures for establishing both quantitative and qualitative response to the major algal nutrients. It has been particularly important that these determinations be based upon a reference procedure so that effective regional comparisons could be carried out. With this in mind a joint industry government task force on eutrophication encouraged development and publication of provisional assay procedures for use in predicting the impact of nutrient elements and nutrient-synergistic compounds upon aquatic productivity in natural waters.[1]

An intensive coordinated program of development and evaluation followed involving university and industrial laboratories. Both batch or bottle test and continuous culture algal bioassays were evaluated as to their applicability for establishing limiting nutrient levels in surface waters.[2,3] Following detailed definition of the growth constraints for the batch test, eight laboratories participated in a joint evaluation of the assay bottle procedure as reported by Weiss and Helms.[4] The same water samples were distributed to each of the eight laboratories and batch tests were carried out using a standardized assay protocol. This interlaboratory comparison established that whereas there was a low level of precision between the results of the participating laboratories, variation being over 30%, within any one laboratory the precision was considerably better. Unknown systematic errors may have contributed to the magnitude of difference in biomass grown at the several laboratories.

It was stated in the original industry/government task force recommendation on the algal assay procedure that when the developmental phase was completed an extensive field evaluation should be undertaken. Without this correlation to the conditions in nature, the true relationship of the results obtained from the assay procedure would still remain uncertain. One of the immediate and very useful applications of the algal assay has been to establish the extent of response of batch cultures to environmental safety evaluations of raw materials that might be considered for use in consumer products, Sturm and Payne,[5] Payne,[6] Mitchell and Buzzel.[7] Examples of algal response in natural systems using the batch assay to establish trophic levels and identification of growth limiting nutrients have been used by Toerien and Steyn,[8] Francisco and Weiss,[9] Steyn et al.[10] Miller et al.,[11] Payne,[12] Doemel and Brooks,[13] and Greene et al.[14]

SECTION II

SUMMARY

The 345 algal assays of surface water samples from lakes, rivers and impoundments of North Carolina carried out over a period of about five years included the pretreatment procedure of autoclaving or membrane filtration. This step destroyed or removed living algal cells and permitted reseeding with a specific test species, Selenastrum capricornutum. Subsequent growth under controlled temperature and light conditions permitted comparison of biomass grown in the pretreated (autoclaved or filtered) media and that in waters to which known quantities of phosphorus and nitrogen were added. The growth in the spiked samples provided an indication of whether phosphorus, nitrogen or both might be growth limiting in the original water. The growth in the unspiked water also provided reference to the scale of ambient nutrient levels and the trophic state of the original surface water source.

The control algal biomass grown in water with indicated phosphorus limitation, 104 assays after autoclaving as pretreatment, had a mean concentration of 5.31 mg/l whereas filtered phosphorus limited waters, 191 assays, had a mean biomass of 1.37 mg/l. Nitrogen limited water after autoclaving, 132 assays, had a mean biomass of 12.15 mg/l and 9.81 mg/l following filtration as the pretreatment. Where both phosphorus and nitrogen were indicated as limiting following autoclaving, 105 assays, the mean biomass was 4.70 mg/l and 0.92 mg/l after filtration.

The implication of these findings is that the autoclaving pretreatment procedure probably provides a better indication of potential growth capability whereas the filtered samples reflect the growth capability of ambient nutrient levels.

A consistent pattern of the ratio of the soluble nitrogen and phosphorus components to the indicated limitation of either one, the other, or both of these algal nutrients suggest that this ratio can be used to define which nutrient is limiting for the particular body of water.

SECTION III

CONCLUSIONS

The growth of the reseeded test alga, Selenastrum capricornutum, in water samples following pretreatment either by autoclaving or filtration provides a good indication of the total growth potential by the first procedure and ambient growth potential by the second. The growth response of samples to which spikes of phosphorus and nitrogen have been added established the nature of the growth limiting nutrient. Reference to original nutrient levels clearly indicated ranges of nitrogen to phosphorus ratios necessary for optimum support of the test organism. The determination of the N/P ratio appears to provide the same information as derived from the more complicated assay spiking procedure providing other essential nutrients or inhibitors are not growth limiting.

SECTION IV

RECOMMENDATIONS

The standard assay procedure could be modified to limit the determination to biomass grown in reseeded samples following autoclaving and filtration. The determination of whether the waters are limited in their growth potential by the relative quantity of phosphorus or nitrogen can be satisfactorily determined from the ratio of the total soluble nitrogen and phosphorus components if other constituents are not growth limiting.

SECTION V

EXPERIMENTAL PLAN

One of the basic problems inherent in the batch algal assay procedure is the necessary pretreatment required of the water sample, either filtration through a 0.45μ membrane filter or autoclaving followed by filtration to remove particulate and insoluble materials. Either pretreatment is essential in order to remove or destroy living algal cells so that reseeding with the test alga is possible. Using filtration, the assumption is made that all remaining nutrient components in solution would reflect the growth limiting nutrient: regulating further natural biomass production. In the use of autoclaving, which also solubilizes nutrient materials, algal growth would reflect the total nutrient potential assuming temperature, light and other growth factors were not limiting. In either case if the assay is meaningful the magnitude of growth of the reseeded sample should relate to the trophic state or the limiting nutrient potential of the original water sample. In this field evaluation algal assays were used to establish the relationship between the existing trophic or nutrient level of 44 different bodies of water, sampled at several locations, as well as several frequencies, for a total of 345 assays. The location and type of the sampled waters is shown in Figure 1. The name, identification code and size with approximate magnitude of pollution entering each body of water is presented in Table 1.

TABLE 1. SURFACE WATERS OF NORTH CAROLINA AND ADJACENT AREAS EVALUATED BY ALGAL ASSAY

Type and Name	Surface Area (Acres)	Mean Depth-ft.	Stations Sampled	Pollution Sources: Direct Point Discharge	Pollution Sources: Inflowing River**
Natural Lakes					
1 Black	1,418	6*	2	No	No
2 Jones	224	6*	2	No	No
3 Mattamuskeet	30,000	4*	1	No	No
4 Phelps	16,000	6*	1	No	No
5 Salters	315	6*	2	No	No
6 Singletary	572	6*	2	No	No
7 Waccamaw	8,938	6*	2	No	No
8 White	1,068	8*	2	No	No
Impounded Cooling Lakes					
9 Belews	3,700	50	2	No	No
10 Hyco	3,750	21	2	No	No

(Continued)

TABLE 1. SURFACE WATERS OF NORTH CAROLINA AND ADJACENT AREAS EVALUATED BY ALGAL ASSAY Continued

Type and Name	Surface Area (Acres)	Mean Depth-ft.	Stations Sampled	Pollution Sources: Direct Point Discharge	Pollution Sources: Inflowing River**
Water Supply Impoundments					
11 University	200	9	1	No	No
12 Michie	507	25	1	No	No
Hydroelectric Impoundments					
Catawba River					
13 James	5,510	46	4	Yes	No
14 Rhodhiss	3,515	21	6	Yes	No
15 Hickory	4,110	31	3	Yes	No
16 Lookout Shoals	1,270	24	3	No	No
17 Norman	32,510	34	6	No	No
18 Mt. Island	3,235	18	3	No	No
19 Wylie	12,455	22	8	Yes	No
20 Fishing Creek	3,370	17	2	No	Yes
21 Wateree	13,710	23	5	No	Yes
Yadkin River					
22 W. Kerr Scott (Flood Control)	3,980	38	3	No	No
23 High Rock	15,180	16	3	No	Yes
24 Tuckertown	2,529	17	3	No	No
25 Badin	5,973	24	3	Yes	No
26 Tillery	5,000	34	7	No	Yes
27 Blewett Falls	2,500	36	3	Yes	No
Roanoke River					
28 John H. Kerr	48,900	34	11	Yes	Yes
29 Gaston	22,000	18	3	No	No
30 Roanoke Rapids	4,900	16	3	No	No

(Continued)

TABLE 1. SURFACE WATERS OF NORTH CAROLINA AND ADJACENT AREAS EVALUATED BY ALGAL ASSAY Continued

Type and Name	Surface Area (Acres)	Mean Depth-ft.	Stations Sampled	Pollution Sources: Direct Point Discharge	Pollution Sources: Inflowing River**
Old Millponds					
31 Crystal (1885)***	100	6*	1	No	No
32 Davies (1850)	50	6*	1	No	No
33 Finches (1875)	20	6*	1	No	No
34 Hodgins (1871)	100	5*	1	No	No
35 Jackson (1885)	75	10*	1	No	No
36 Johns (1840)	125	8*	1	No	No
37 Jones (1810)	75	3*	1	No	No
38 Lytches (1870)	325	7*	1	No	No
39 McKensie (1860)	50	7*	1	No	No
40 McNeils (1870)	100	4*	1	No	No
41 Monroe (1825)	70	5*	1	No	No
42 Orton (1810)	500	8*	1	No	No
43 Tull (1875)	180	6*	1	No	No
River Segments					
44 Chowan (U.S. 13 to Albemarle Sound)	-		6	Yes	-

* Estimated.
** Yes if river carries pollution discharges from upstream communities with no intervening impoundments.
*** Year of construction.

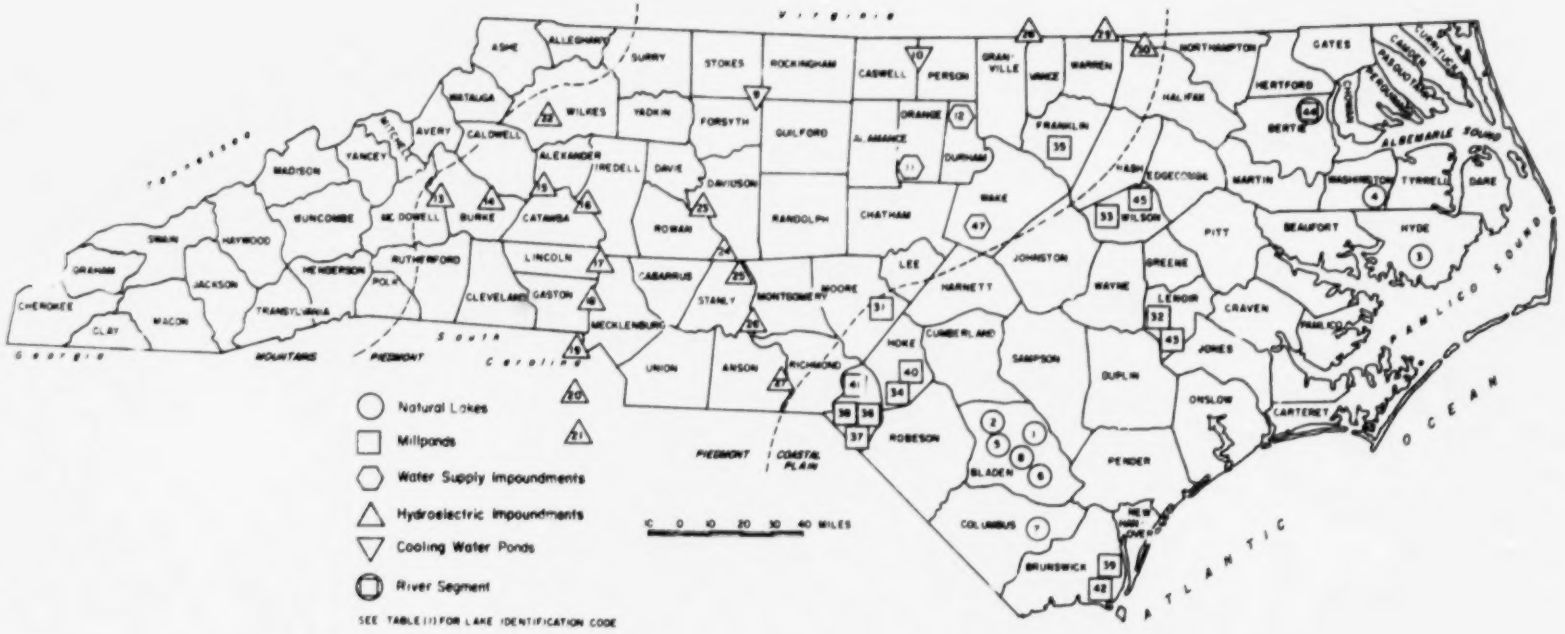

Figure 1: Location and Nature of Waters Sampled in North Carolina and Adjacent Areas for Algal Assays.

SECTION VI

METHODS AND PROCEDURES

In order to accommodate the considerable number of samples being processed over the several years of this study and to stay within the recommended procedures of the "bottle test" the growth response of the reseeded samples were determined only at the end of a fixed period of incubation. It has been shown in the developmental steps of the assay procedure that biomass achieves a level of growth proportionate to available nutrients in 10 to 14 days with occasional samples, depending on the particular character of the water, requiring upwards of 21 days to achieve the growth plateau.[2] For this field evaluation the assay protocol was standardized as follows:

1. Each raw water sample was split into two portions - one for autoclaving and one for filtration (0.45μ filter) as pretreatment procedures.

2. Each of the samples following pretreatment was divided into subsets of three portions, each 60 ml in 250 ml Erlenmeyer flasks, and spiked to provide a final additional concentration of 5 and 50 μg/l of phosphorus, 75 and 750 μg/l of nitrogen, 5 μg/lP plus 75 μg/lN, and 50 μg/lP plus 750 μg/lN. In addition another set of three flasks was used as a nonspiked control.

3. Each flask was seeded with 1,000 cells/ml of Selenastrum capricornutum previously washed and resuspended in distilled water to adjust to the inoculation concentration. The inoculum was cell culture grown 10-21 days in New Algal Assay Media (NAAM).[2]

4. The seeded flasks were placed in an incubator at 24°C+2.0°C under 400 ft. candles of "daylight" fluorescent illumination.

5. Incubation was for 14 days with a daily swirling of the cutlure flasks.

6. The standard control media NAAM, in a replicate set of flasks, and seeded from the same cell suspension of S. capricornutum was incubated for the same period as each assay set.

7. At the end of the growth period the optical density of the cell suspension was determined using a Bausch and Lomb Spectronic 20 colorimeter at a wavelength of 640 mμ. In addition the total biomass grown in the NAAM control samples was optically measured, filtered and weighed and used to determine the unit absorbance for the particular growth conditions of that incubation set.

8. The unit of absorbance of the NAAM control for each incubation set was used to convert the unit absorbance of the spiked samples and controls to biomass.

The requirement of maintaining extensive records over a relatively long period of time on the algal assays led to systematizing the procedures for computer conversion of data. Data record forms were designed to accommodate the basic information of each water sample from which data cards were punched, programs written for data analysis and a good deal of the computational work processed by computer.

At the time of collection of the original water sample on which the algal assay was to be carried out, a broad spectrum of limnological parameters were also determined. From these the original trophic state could be established for comparison to the nutrient characteristics as determined by the algal assay.

All analyses of the several nitrogen and phosphorus species were made using Technicon Autoanalyzers. For the purposes of this investigation the nitrogen and phosphorus forms are defined or were determined as follows:

NH_3-N	Ammonia nitrogen.
NO_2+NO_3-N	One analysis which includes oxidation of NO_2 to NO_3 and the total determined.
Inorganic-N	The sum of NH_3-N and NO_2+NO_3-N.
Kjel-N	Kjeldahl nitrogen.
Total-N	NO_2+NO_3-N plus Kjel-N.
PO_4-P	Orthophosphate phosphorus, soluble reactive phosphorus.
T-Sol P	Total soluble phosphorus. The total fraction that passes the 0.45 micron filter and is digested by autoclaving with persulfate.
T-Particulate P	Total-P minus total soluble P.
T-P	Total Phosphorus. The total raw sample digested by autoclaving with persulfate.

Phytoplankton cell counts were determined on live samples, concentrated by centrifugation with a clinical centrifuge. The resuspended concentrate was transferred to a microscope slide and sealed under a 22x22mm cover glass. Transects were counted at 500X and specific identifications made at 1250X. Cell density was calculated from the cover glass area, area of transects counted and original volume concentrated.

The chlorophyll *a* determinations were made on a Turner photo-fluorometer equipped with a photo detector that enhanced its sensitivity to chlorophyll fluoresence. Comparison of the values determined with a Turner photo-fluorometer and the standard acetone extraction procedure showed a high level of correlation. However, since the conversion factor appeared to vary somewhat from lake to lake the Turner scale unit has been used in this report as the chlorophyll unit. An approximate conversion to chlorophyll *a* mg/l can be made by multiplying Turner units by 0.44.

Since it was realized that determination of in situ primary productivity would not be logistically feasible in all cases, a procedure that would allow for direct comparison of productivity between lakes was used. Following suitable experiments to define optimum conditions all raw water samples collected for productivity determinations were returned to the laboratory in polyethylene bottles and stored overnight in the dark at room temperatures. The next day a light/dark bottle set (2 light, one dark) were filled with the raw water sample and after initial dissolved oxygen determinations incubated at 24°C and 400 f.c. for six hours. The rate of carbon fixed per hour was computed from the net oxygen production. The same samples returned to the laboratory for primary productivity determinations also provided the water source for chlorophyll *a* measurements and plankton counts.

SECTION VII

RESULTS AND DISCUSSION

NUTRIENT CHARACTERIZATION OF NORTH CAROLINA LAKES

Limnological Parameters

Sampling for algal assay has coincided in most instances with other water quality investigations of North Carolina waters. Results of some assays have already been used to define algal growth conditions of specific locales or to help define trophic states.[15,16,17,18] At time of sampling a variety of limnological parameters were also defined. In general samples for algal assay were taken either from mid-epilimnetic or Secchi disc depth, the choice approximating the mid-depth of the euphotic zone. The mean values of those parameters that either define the conditions for algal growth or the result of algal growth have been assembled in Appendix A for each lake or where meaningful for stations or sets of stations within a lake.

The data has also been classified into two seasonal periods, April through November and December through March. The experience of sampling North Carolina waters has shown that these two seasonal segments generally define, a more active growing season, in the case of the former and a winter season of somewhat lesser growth activity. However, the difference between the two seasons, with respect to algal growth, is often quite small. Light is probably the overall principal limiting factor rather than temperature.

Belews Lake and Lake Hyco, cooling pond impoundments are each represented by two stations at points on the lakes, which describe different environmental conditions. University Lake and Lake Michie, water supply impoundments were sampled only at one station near the water supply intake. Of the Catawba River impoundments, Lakes James, Rhodhiss, Norman, Mt. Island, Fishing Creek and Wateree are limnologically described by averaging data of more than one station on each lake. Two adjacent impoundments, on the Catawba River, Hickory and Lookout Shoals had their data combined into one profile whereas the data for Lake Wylie is presented by separate station sets representing both organic and thermal pollution conditions. The Yadkin River impoundments, Kerr Scott, High Rock, Tuckerton, Badin, Tillery and Blewett Falls are each described independently whereas the large flood control and hydro-power impoundment, John H. Kerr was sampled and analyzed by sets of stations representing changes in water quality along its two flow-through gradients. Similarly the data from the Chowan River was analyzed by sets of stations representing points of change in water quality. All the small mill ponds and the few natural lakes, generally represented by one sample, are summarized independently. Generally lakes of similar nature or location are arranged on the same page in order to facilitate comparison.

Nutrient Profiles

The range of values for nutrient levels and biological parameters within the two seasonal segments of the year, and the associated physical and chemical determinations have been described for the assayed waters. This was accomplished using sorting procedure on the card punched limnological data for each lake. A first step would be to arrange the nearly 350 data cards in rank order for one of the nutrient components. For example, for inorganic nitrogen, the lowest value of the entire series was 20 mg/m^3 and the highest 1245 mg/m^3. The entire set of inorganic nitrogen values was then divided into four subsets having ranges of 20-120 mg/m^3, 130-245 mg/m^3, 250-400 mg/m^3 and the highest 500-1245 mg/m^3. A suitable computer program then selected out all lake samples in each of the five ranges, as defined by the quantity inorganic nitrogen, and calculated mean values for all other variables within that set, Table 2. In the April-November growing season, the 68 samples which occurred in the range of 20-120 mg/m^3 inorganic nitrogen had an average water temperature of 25.2°C, an average Secchi depth of 1.5 m, an ammonia nitrogen concentration of 35.5 mg/m^3, etc. If for some reason the data set was incomplete for a particular parameter the actual number of samples used in the average is identified in a parenthesis following the value. For example the mean value of 37.1 Turner units for chlorophyll *a* was defined by averaging 53 samples rather than the total number of 68 for that seasonal set. This method of data analysis established that over the five ranges of inorganic nitrogen the total soluble phosphorus increased from 11.8 mg/m^3, the mean value for those water samples which had inorganic nitrogen concentrations in the range of 20-120 mg/m^3 to a total soluble phosphorus concentration of 54.4 mg/m^3 associated with the highest range of inorganic nitrogen.

Of most significance to the ultimate concern of this study, the relationship of the algal assay to the trophic state of the raw waters, would be the three biological determinations. Phytoplankton cell density, chlorophyll *a*, and productivity and their relationship to the ranges of the nutrient levels. As an example the cell density, Table 2, decreased systematically with increase in inorganic nitrogen concentration. By contrast chlorophyll *a* remained relatively constant throughout the range of concentrations but productivity appeared to have a peak value in midrange. All these changes were in samples taken in the April-November growing season. Such comparisons can be made with other parameters and other related components and provides an opportunity to establish the relationships of the mean values of various associated parameters.

The sorting and averaging procedure was carried out for total nitrogen, Table 3; total soluble phosphorus, Table 4; total phosphorus, Table 5; and the ratio of total nitrogen to total phosphorus, Table 6. It should be noted that in each instance the particular values used to define the upper and lower limit of a range was an actual determination and not an arbitrary division of the total rank of values. Thus there might be a gap between upper and lower limits of ranges since the omitted values did not actually occur in the total range of values.

A similar sorting procedure was carried out for the three biological determinations, phytoplankton, cell density, chlorophyll *a*, and productivity to determine the mean values of nutrients that were associated with the ranges selected for averaging. The data of Table 7 examines the total range of cell density from a low of 62 cells per ml to the maximum value of 82,671 cells/ml, in five sets. In the April-November growing season the soluble components of

TABLE 2. PHYSICAL, CHEMICAL AND BIOLOGICAL PARAMETERS, ALL LAKE SAMPLES USED IN ALGAL ASSAYS, MEAN VALUES WITHIN VALUE RANGE OF INDICATED PARAMETER: INORGANIC NITROGEN (NH_3+NO_2NO_3) mg/m^3

Sample Period	April - November				December - March			
Range of Values mg/m^3	20-120	130-245	250-400	500-1245	20-120	130-245	250-480	500-1245
N	68	65	50	17	12	19	46	17
Water Temp. °C	25.2	19.1	19.4	15.3	13.9	11.5	9.6(35)	11.2
Secchi Depth-m	1.5	1.2	0.8(44)	0.4	1.2	1.1	0.8	0.6
NH_3-N*	35	59	56	199	44	72	63	272
NO_2NO_3	30	119	238	443	92	119	260	426
Inorganic-N	64	182	327	671	69	190	338	730
Kjel-N	341	318	387	450	287	301	265	598
Total-N	361	405	585	912	335	420	537	1035
PO_4-P	7.3	11.5	17.4	21.9	6.6	17.6	10.6	69.1
T-Soluble P	11.8	18.7	32.4	54.4	14.6	25.3	22.8	93.4
T-Particulate P	15.0	15.8	21.3	49.7	12.5	31.2	19.9	44.4
Total-P	26.5	35.5	50.1	105.3	29.4	57.1	41.2	137.4
TN/TP	17.6	18.5	16.0	12.4	15.1	15.4	16.9	12.5
Cell Density no./ml	6444	3411	3181	1190	3864	5320(16)	2353(33)	2559
Chlor a Turner Units	37.1(53)	32.5(40)	33.8(24)	30.1(14)	39	53.3(13)	24.5(30)	36.5(13)
Productivity $mgC/m^3/hr.$	36.3(26)	54 8(16)	42.0(4)	26.5(2)	144(1)	445(14)	41.1(15)	78.4(5)

*All N and P concentrations mg/m^3

TABLE 3. PHYSICAL, CHEMICAL AND BIOLOGICAL PARAMETERS, ALL LAKE SAMPLES USED IN ALGAL ASSAYS, MEAN VALUES WITHIN VALUE RANGE OF INDICATED PARAMETER: TOTAL NITROGEN - mg/m^3

Sample Period	April - November				December - March			
Range of Values mg/m^3	120-260	270-495	510-830	910-1580	120-260	270-495	510-830	910-1580
N	36	90	57	17	3	44	35	12
Water Temp. °C	21.2	21.3	20.7	19.7	14.4	11.3	9.6(24)	11.5
Secchi Depth-m	1.6	1.3	0.8	0.5	2.1	1.0	0.6	0.6
NH_3-N*	51	49	58	166	30	58	93	296
NO_2NO_3	91	155	208	310	155	168	295	372
Inorganic-N	91.9	178	282	506	71.6	235	381	714
Kjel-N	193	285	456	654	135	224	323	837
Total-N	212	371	665	983	191	399	621	1204
PO_4-P	10.5	11.5	12.1	22.5	6.6	9.6	17.6	84.5
T-Soluble P	12.8	18.9	26.3	50.0	13.3	16.5	32.9	113
T-Particulate P	7.4	14.9	25.7	52.1	11.3	16.5	29.7	50.8
Total-P	22.7	31.6	51.9	103	28.3	32.4	62.8	163
TN/TP	17.0	17.9	16.1	15.8	14.5	18.9	11.8	14.5
Cell Density no./ml	2206(30)	4234(62)	4347(42)	8965	2534	2940(39)	2360(23)	6579(10)
Chlor a Turner Units	24(27)	30(56)	43(38)	55(10)	16	29(36)	29(19)	72(9)
Productivity $mgC/m^3/hr.$	20(8)	36(21)	51(14)	83(5)	23(1)	45(17)	32(12)	114(5)

*All N and P concentrations mg/m^3

TABLE 4. PHYSICAL, CHEMICAL AND BIOLOGICAL PARAMETERS, ALL LAKE SAMPLES USED IN ALGAL ASSAYS, MEAN VALUES WITHIN VALUE RANGE OF INDICATED PARAMETER: TOTAL SOLUBLE-P - mg/m^3

Sample Period	April - November				December - March			
Range of Values mg/m^3	5-19	20-40	45-80	90-390	5-19	20-40	45-80	90-390
N	102	57	17	6	42	33	9	6
Water Temp. °C	22.0	19.3	17.7	17.1	11.8	9.3	12.2	11.7
Secchi Depth-m	1.4	0.9	0.6	0.6	1.0	0.8	0.5	0.7
NH_3-N*	50	77	105	87	56	86	204	340
NO_2NO_3	89	193	347	318	191	271	336	344
Inorganic-N	146	269	408	356	260	333	540	685
Kjel-N	290	395	453	444	236	336	435	886
Total-N	378	577	682	646	440	589	771	1230
PO_4-P	6.4	10.4	31.0	77.2	5.3	13.1	42.0	187
T-Soluble P	8.4	25.5	60.1	130	10.4	27.1	65.5	213
T-Particulate P	13.1	25.1	41.8	27.5	13.6	31.1	48.3	52.5
Total-P	22.7	51.5	100	145	24.0	59.1	113	265
TN/TP	21.2	13.6	8.1	7.1	21.6	11.6	7.3	5.1
Cell Density no./ml	4260(86)	3492(47)	9940(12	1327(4)	2844(36)	2793(25)	5107(7)	5299
Chlor a Turner Units	30(77)	39(39)	47(2)	30(3)	28(37)	36(16)	49(7)	58
Productivity $mgC/m^3/hr.$	34(34)	51(11)	149(12)	-	31(16)	50(16)	179(1)	138(2)

*All N and P concentrations mg/m^3

TABLE 5. PHYSICAL, CHEMICAL AND BIOLOGICAL PARAMETERS, ALL LAKE SAMPLES USED IN ALGAL ASSAYS, MEAN VALUES WITHIN VALUE RANGE OF INDICATED PARAMETER: TOTAL-P - mg/m^3

Sample Period	April - November				December - March			
Range of Values mg/m^3	5-18	20-40	43-80	85-410	5-18	20-40	43-80	85-410
N	53	81	36	27	16	35	27	17
Water Temp. °C	22.2	22.1	19.5	17.5	10.7	10.9	11.4	10.5
Secchi Depth-m	1.7	1.1	0.8	0.5	1.3	0.9	0.6	0.6
NH_3-N*	38	60	60	113	58	71	82	241
NO_2NO_3	69	108	194	341	179	197	260	342
Inorganic-N	122	188	269	428	249	285	326	584
Kjel-N	224	382	422	489	180	280	333	588
Total-N	298	470	575	725	375	485	589	930
PO_4-P	5.6	8.0	13.8	34.6	4.9	6.5	13.7	82.4
T-Soluble P	7.4	14.7	28.9	63.2	7.7	14.8	28.0	109
T-Particulate P	4.5	13.6	31.4	52.6	5.3	13.9	28.9	62.6
Total-P	11.8	27.5	60.2	118.0	12.5	28.2	57.8	172
TN/TP	24.7	17.8	11.1	8.3	29.5	18.1	10.4	6.1
Cell Density no./ml	2113(44)	5038(59)	5070(26)	7249(18)	1084(13)	3482(27)	3459(18)	4337
Chlor *a* Turner Units	24(41)	32(49)	50(23)	44(17)	18(13)	31(27)	37(14)	56(12)
Productivity $mgC/m^3/hr.$	13(12)	43(26)	56(6)	124(3)	21(3)	33(16)	69(10)	77(6)

*All N and P concentrations mg/m^3

TABLE 6. PHYSICAL, CHEMICAL AND BIOLOGICAL PARAMETERS, ALL LAKE SAMPLES USED IN ALGAL ASSAYS, MEAN VALUES WITHIN VALUE RANGE OF INDICATED PARAMETER: RATIO TN/TP

Sample Period	April - November					December - March				
Range of Values ratio	1.9-6.8	7.0-10.8	11.0-15.7	15.0-21.5	22.0-87.0	1.9-6.8	7.0-10.8	11.0-15.7	16.0-21.5	22.0-87.0
N	14	42	46	44	50	11	25	26	13	18
Water Temp. °C	20.5	20.1	20.2	21.9	21.9	13.3	10.1	10.9	11.1	10.5
Secchi Depth-m	0.8	0.7	1.2	1.3	1.4	0.6	0.6	0.9	0.9	1.2
NH_3-N*	73	71	61	55	52	185	144	85	66	79
NO_2NO_3	164	240	122	84	123	330	243	225	156	263
Inorganic-N	271	301	202	152	187	516	367	299	264	335
Kjel-N	486	364	302	357	360	472	357	327	317	238
Total-N	648	545	402	435	465	802	609	545	508	499
PO_4-P	34.7	16.1	11.3	7.2	8.0	101	17.2	10.7	6.9	5.1
T-Soluble P	61.9	36.9	21.0	11.7	9.3	130	34.4	23.9	14.1	9.4
T-Particulate P	55.5	35.6	13.5	12.5	6.4	60.9	37.5	19.0	13.5	7.2
Total-P	113	64.6	36.5	24.3	19.4	191	70.7	43.5	26.8	16.6
TN/TP	5.1	8.5	13.5	17.9	30.6	4.7	8.7	13.0	17.9	32.7
Cell Density no./ml	12306(10)	3350(28)	3818(35)	4583(40)	3048(33)	4963	4039	3266(20)	2669	1130(13)
Chlor a Turner Units	72(8)	39(27)	28(32)	36(33)	24(27	56(9)	40(16)	32(16)	32(11)	19(14)
Productivity $mgC/m^3/hr$	124(3)	57(6)	32(14)	49(12)	22(13)	230(2)	44(4)	26(8)	54(7)	18(4)

*All N and P concentrations mg/m^3

TABLE 7. PHYSICAL, CHEMICAL AND BIOLOGICAL PARAMETERS, ALL LAKE SAMPLES USED IN ALGAL ASSAYS, MEAN VALUES WITHIN VALUE RANGE OF INDICATED PARAMETER: CELL DENSITY No./ml

Sample Period	April - November					December - March				
Range of Values no./ml	62-599	604-1183	1210-2366	2449-9926	13085-82671	62-599	604-1183	1210-2386	2449-9926	11308-82671
N	23	26	41	46	14	22	22	7	23	7
Water Temp. °C	15.8	17.3	22.0	22.9	27.2	10.9	10.5	11.5	11.5	11.8
Secchi Depth-m	0.8	1.1	1.3	1.2	1.0	1.0	0.9	0.8	0.9	0.7
NH_3-N*	133	75	67	55	35	75	116	189	74	151
NO_2NO_3	232	180	132	92	99	224	275	284	221	93
Inorganic-N	345	275	204	147	134	299	392	473	295	203
Kjel-N	339	295	305	354	496	311	275	429	318	786
Total-N	559	488	432	447	595	535	551	713	540	806
PO_4-P	14.9	7.7	10.0	9.1	13.2	17.6	27.2	49.3	18.0	29.1
T-Soluble P	32.9	18.5	18.7	15.9	20.3	28.6	41.6	56.1	27.0	45.4
T-Particulate P	32.0	15.6	16.9	18.0	33.3	22.4	27.9	30.3	22.0	79.3
Total-P	64.2	33.6	35.8	33.9	53.7	51.1	69.5	86.4	49.0	144
TN/TP	14.9	21.5	16.0	17.5	14.7	16.8	16.3	15.5	13.9	8.4
Cell Density no./ml	410	905	1801	4803	23326	305	902	1712	5090	25397
Chlor *a* Turner Units	21	18(22)	33(37)	42(40)	67(11)	20(18)	20(19)	31(5)	37	138
Productivity $mgC/m^3/hr$	-	15(7)	31(10)	44(18)	80(9)	5(9)	27(9)	40(5)	64(15)	176

*All N and P concentrations mg/m^3

nitrogen show a clearly indicated inverse relationship between cell number and nutrient. However, the phosphorus mean values are less systematic in their relationship to cell number except that the overall values in the winter period seem to be somewhat higher than comparable values in the April-November growing season.

A similar sorting for chlorophyll a, Table 8, in four ranges of values, shows a strong positive relationship to cell density and productivity, as would be expected, and to Kjeldahl nitrogen another direct measure of materials of biological origin. Nevertheless, the phosphorus relationship continues to be ambiguous with higher mean values at the extreme ends of the ranges than found in the midranges.

The sorting of the variable productivity, Table 9, describes, for those samples taken in the growing season, a parallel increase in organic nitrogen and soluble phosphorus with an increase in productivity. The mean values for cell density and chlorophyll a show a similar parallelism. Explanations for some of the anomalies may be explained in part by the fact that cell density may not be as precise a measure of biological production as cell volume which is probably more accurately reflected in the measurements of chlorophyll a and productivity. It might be noted here that the ratio between total nitrogen and total phosphorus appears to be linked to biological activity. In the case of both chlorophyll a and productivity these parameters increased as this ratio systematically decreased.

ALGAL ASSAY

Growth in NAAM

One aspect of the algal assay that was clearly established by the "inter-laboratory precision test" was the degree variability between laboratories even though within a laboratory the degree of precision could be maintained at a reasonable level.[4] One approach to establishing the reliability of the algal assay is the use of a growth control, employing the NAAM media, with each of the spiked, pre-treated samples. This is essential to the determination of biomass grown in the spike samples which is based on the dry weight determination of biomass grown in NAAM under the same conditions and at the same time as that of the specific spiked series. To provide some indication of the variability of the assay procedure over the time span of several years of this assay evaluation all of the samples grown in NAAM in conjunction with each of the specific lake samples have been arranged in Table 10. This table describes the actual dry weight determination of biomass, maximum, minimum and mean values, standard deviation, the unit absorbance for these same samples, and the mean values and standard deviation for unit absorbance.

It is clear that over a period of several years variability is inherently built into a bioassay because of changes in personnel which leads to small changes in procedures in the assay protocol, changes in purity of chemicals and perhaps even changes in the growth response of the specific alga used in the assay. However, the biomass determinations, as systematically grown in NAAM do indicate that on the average the values are comparable over the several years. The standard deviation of the sets indicate a variation on the order of 10-20% of

TABLE 8. PHYSICAL, CHEMICAL AND BIOLOGICAL PARAMETERS, ALL LAKE SAMPLES USED IN ALGAL ASSAYS, MEAN VALUES WITHIN VALUE RANGE OF INDICATED PARAMETER: CHLOROPHYLL a TURNER UNITS

Sample Period	December - March				April - November			
Range of Values Units	8-14	16-30	31-60	64-139	8-14	16-30	31-60	64-139
N	15	64	40	12	17	24	19	6
Water Temp. °C	18.6	19.5	23.5	25.8	10.1	12.0	11.7	11.7
Secchi Depth-m	1.6	1.2	1.1	0.7	1.2	0.8	0.9	0.6
NH_3-N*	82	86	59	36	94	104	102	160
NO_2NO_3	71	174	111	148	270	248	240	162
Inorganic-N	148	260	174	183	364	352	342	322
Kjel-N	216	288	333	617	215	309	353	738
Total-N	278	462	445	765	486	556	593	900
PO_4-P	19.6	7.2	9	19.5	16.7	28.1	23.7	54.0
T-Soluble P	26.9	17.9	15.3	43.4	24.2	38.4	40.5	77.1
T-Particulate P	5.1	21.2	17.2	51.6	15.9	23.9	19.0	58.3
Total P	27.5	39.1	33.3	95.0	40.1	62.4	59.6	135
TN/TP	18.9	17.2	16.4	10.0	21.3	14.8	17.2	8.0
Cell Density no./ml	1164	2030	5863	14879	644	1505	4330	18048
Chlor a Turner Units	11	23	41	98	12	22	39	132
Productivity $mgC/m^3/hr.$	7(5)	26(13)	63(13)	106(5)	9(6)	24(7)	81(9)	156(4)

*All N and P concentrations mg/m^3

TABLE 9. PHYSICAL, CHEMICAL AND BIOLOGICAL PARAMETERS, ALL LAKE SAMPLES USED IN ALGAL ASSAYS, MEAN VALUES WITHIN VALUE RANGE OF INDICATED PARAMETER: PRODUCTIVITY - $mgC/m^3/hr$

Sample Period	April - November			December - March		
Range of Values $mgC/m^3/hr$.	1-27	30-57	60-281	1-27	30-57	0-281
N	17	19	11	15	8	8
Water Temp. °C	23.3	23.9	23.5	9.0	9.7	9.8
Secchi Depth-m	2.1	1.2	0.8	1.1	1.0	0.6
NH_3-N*	42	46	76	85	41	219
NO_2NO_3	56	95	116	166	214	178
Inorganic-N	100	167	192	251	256	297
Kjel-N	285	359	533	249	249	710
Total-N	343	472	649	415	463	888
PO_4-P	6.1	7.2	15.9	9.0	6.2	28.0
T-Soluble P	8.9	13.6	24.4	16.3	14.5	53.7
T-Particulate P	5.1	16.3	41.9	16.4	21.5	54.4
Total-P	13.9	29.2	66.3	32.7	36.0	108
TN/TP	25.2	15.5	14.1	16.9	14.9	10.4
Cell Density no./ml	2422	9446(17)	14124	1493	4211	13314
Chlor a Turner Units	18(12)	36(14)	71	16(11)	37	110
Productivity $mgC/m^3/hr$	14	40	95	13	44	150

*All N and P concentrations mg/m^3

TABLE 10. GROWTH OF SELENASTRUM CAPRICORNUTUM IN NAAM (14 DAYS, 24°C, 400 f.c.); MEAN VALUES OF BIOMASS AND UNIT ABSORBANCE

Lake(s)	Time Span of Assays	Number of NAAM Samples Used	Biomass in NAAM, mg/l				Unit Absorbance			
			Max.	Min.	Mean	S.D.	Max.	Min.	Mean	S.D.
University, Michie	Oct. 12, 1971-Sept. 11, 1973	13	148.8	110.9	125.0	10.6	307.1	225.9	259.1	23.5
Belews, Hyco	Oct. 8, 1971-Aug. 9, 1974	19	144.3	88.4	119.3	12.6	403.1	211.1	263.7	45.8
Kerr, Gaston, Roanoke Rapids	Sept. 20, 1971-Jan. 7, 1975	20	136.9	85.1	114.9	13.1	275.1	182.0	240.2	33.9
Chowan River	Sept. 7, 1972-Aug. 10, 1973	4	131.8	117.5	125.1	6.1	262.0	232.1	247.5	14.5
Kerr Scott, Yadkin High Rock, Tuckertown, Badin, Tillery Blewett Falls	Dec. 6, 1971-Jan. 7, 1975	7	123.2	92.2	107.7	13.8	259.4	207.6	230.2	17.4
James, Rhodhiss, Hickory, Lookout Shoals	Nov. 15, 1971-Sept. 24, 1974	8	135.9	67.8	112.1	20.4	367.9	178.8	252.7	53.1
Norman, Mt. Island Wylie, Fishing Creek Wateree	Nov. 15, 1971-Sept. 24, 1974	7	113.4	101.8	119.2	11.6	367.9	235.0	268.6	46.3
Norman, Mt. Island Wylie, South Fork Wateree	Sept. 14, 1973-June 25, 1974	16	123.2	83.9	110.0	10.0	309.0	200.9	266.7	28.3
Mill Ponds and Mattamuskeet, Phelps Salters, Singletary Waccamaw, White	Oct. 27, 1971 Jan. 21, 1975	6	114.1	85.1	99.7	11.1	367.9	182.0	242.5	65.0

the mean. Growth of the test alga in medias or waters of low nutrient concentrations have shown greater variability. It is such variation that must be kept in mind in evaluating the utility of a bio-assay. In this particular study it has been instrumental in determining the approach used in the final evaluation of the results.

Assay for Limiting Nutrients

The procedure for establishing the nature and quantity of limiting nutrients in a surface water is to determine the growth response of a seeded sample, to the addition of phosphorus and nitrogen nutrient supplements or spikes, following pretreatment either by autoclaving or filtration. For the summary of the extensive series of algal assays on the surface waters of North Carolina the growth response of spiked samples has been assembled in a series of tables which describe by the magnitude of the growth, under standard incubator conditions, as to whether growth was limited by phosphorus, nitrogen or both, Tables 11-21. Since the mean growth of the control as well as standard deviation is indicated the significance of any specific response can be readily estimated.

For purposes of this evaluation the biomass grown on addition of specific nutrient spikes were defined by the growth ranges of 0-5, 5.1-15, 15.1-30 and over 30 mg/l. This was growth in excess of that found in the lake control, the biomass grown in the unspiked sample. The growth of the lake control defines ambient nutrient levels. The data of these tables are clustered either by all samples taken from one lake, samples taken from a set of stations in a particular body of water and compared to another set of stations in the same lake or in still other instances where the number of samples taken from any one lake was small, assay results from ponds that showed comparable limnological characteristics were compiled into one set. Biomass in the range 0-5 mg/l was generally indicative of no significant response particularly when examined in relationship to the variation indicated by the size of the standard deviation. Growth at higher ranges, 5.1 mg/l and above, generally described a significant response to the spike and was indicative that the specific nutrient spike or combination was probably limiting to growth.

From the growth response frequencies, the number of samples found in each of the growth ranges, a judgment can be made as to whether the particular body of water was algal growth limiting because of the inadequacy of the amount of phosphorus, nitrogen or both. In reviewing this information two factors need to be kept in mind. For each set of samples the number, (N), will differ and it is this number which defines the total number that can respond in the several growth ranges. In addition the mean growth of the lake control and its standard deviation describe a baseline for referencing the magnitude of growth found in the various spiked samples.

Control Growth at Nutrient Quantities Following Pretreatment Procedures

The data presented in Tables 11-21 provides the opportunity to examine two aspects of the algal assay procedure. One is the relationship of the control growth, nonspiked sample, to the nutrient levels following the two pretreatment procedures, autoclaving and filtration. Does the growth response of the seeded test alga indicate by some degree of correlation the magnitude of the original

TABLE 11. GROWTH RESPONSE OF SELENASTRUM CAPRICORNUTUM IN LAKE SAMPLES, CONTROLS AND ON ADDITION OF NUTRIENT SPIKES OF NITROGEN AND PHOSPHORUS

Lake Station(s) Sample Period	Pretreatment Spike	Autoclaved Mean Growth mg/l Control	Spiked	S.D.	No. Responding, Growth Ranges 0-5	5.1-15	15.1-30	>30 mg/l	Filtered Mean Growth mg/l Control	Spiked	S.D.	No. Responding, Growth Ranges 0-5	5.1-15	15.1-30	>30 mg/l
University	N=20	9.2		10.7					3.1		3.6				
	05P		8.2	7.3	18	2	-	-		4.0	3.3	20	-	-	-
	50P		11.1	7.3	14	5	1	-		10.0	7.8	13	3	4	-
July 1971 -	75N		8.0	6.7	17	3	-	-		3.6	2.7	20	-	-	-
July 1973	750N		10.5	10.4	17	1	2	-		3.5	3.0	20	-	-	-
	5P+75N		9.2	7.3	18	2	-	-		4.2	2.7	18	2	-	-
	50P+750N		27.9	12.3	3	2	13	2		23.1	12.5	4	2	8	6
Michie	N=17	4.4		3.9					2.8		4.2				
	05P		5.1	3.9	17	-	-	-		3.2	2.2	16	1	-	-
	50P		9.5	7.4	10	6	1	-		10.8	8.6	7	6	4	-
July 1971 -	75N		4.2	3.2	17	-	-	-		2.7	2.1	17	-	-	-
July 1973	750N		5.7	6.6	16	-	1	-		2.6	2.0	17	-	-	-
	5P+75N		5.5	3.7	16	1	-	-		3.6	2.4	16	1	-	-
	50P+750N		23.9	12.5	2	4	7	4		24.0	11.7	3	2	7	5
Chowan	N=17	4.3		3.1					1.9		2.3				
13, 17, CO 1, SW 1,	05P		5.6	5.3	15	2	-	-		2.6	2.9	15	2	-	-
	50P		7.2	6.2	13	4	-	-		5.7	4.8	12	5	-	-
Sept. 1972 -	75N		7.9	6.6	13	4	-	-		1.9	3.2	15	-	-	-
Aug. 1973	750N		8.6	5.5	10	6	1	-		3.9	7.6	17	1	-	-
	5P+75N		8.2	6.7	12	5	-	-		2.7	3.1	17	-	-	-
	50P+750N		26.9	13.6	3	1	8	5		19.7	9.4	2	3	12	-
Chowan	N=8	2.3		2.0					1.1		1.5				
A1, RO 45	05P		2.5	2.5	8	-	-	-		1.1	1.3	8	-	-	-
	50P		3.5	2.6	8	-	-	-		3.3	3.9	7	1	-	-
Sept. 1972 -	75N		3.3	2.5	7	1	-	-		1.0	0.8	8	-	-	-
Aug. 1973	750N		3.9	2.9	7	1	-	-		4.2	8.5	7	-	1	-
	5P+75N		4.6	2.9	6	2	-	-		1.7	0.9	8	-	-	-
	50P+750N		24.0	9.7	1	1	5	1		17.1	10.1	1	3	3	1

TABLE 12. GROWTH RESPONSE OF SELENASTRUM CAPRICORNUTUM IN LAKE SAMPLES, CONTROLS AND ON ADDITION OF NUTRIENT SPIKES OF NITROGEN AND PHOSPHORUS

Lake Station(s) Sample Period	Pretreatment Spike	Autoclaved Mean Growth mg/l Control	Spiked	S.D.	No. Responding, Growth Ranges 0-5	5.1-15	15.1-30	>30 mg/l	Filtered Mean Growth mg/l Control	Spiked	S.D.	No. Responding, Growth Ranges 0-5	5.1-15	15.1-30	>30 mg/l
Belews 1906	N=15	1.8		1.8					1.2		1.1				
	05P		2.7	1.8	15	-	-	-		2.1	1.2	15	-	-	-
August 1971 -	50P		5.1	3.9	10	5	-	-		5.6	3.6	10	5	-	-
April 1974	75N		2.0	1.8	15	-	-	-		1.1	0.8	15	-	-	-
	750N		2.0	2.2	15	-	-	-		1.2	1.2	15	-	-	-
	5P+75N		2.9	2.0	15	-	-	-		2.0	2.0	15	-	-	-
	50P+750N		19.5	10.6	1	7	4	3		18.0	12.2	2	6	5	2
Belews 1116	N=15	2.6		1.7					1.3		1.2				
	05P		3.0	1.9	15	-	-	-		1.7	1.2	15	-	-	-
August 1971 -	50P		5.6	3.5	11	4	-	-		4.4	4.4	12	3	-	-
April 1974	75N		2.9	1.7	15	-	-	-		1.5	1.2	15	-	-	-
	750N		2.5	1.9	15	-	-	-		1.2	0.9	15	-	-	-
	5P+75N		3.1	1.6	15	-	-	-		2.0	1.9	14	1	-	-
	50P+750N		19.1	9.7	2	3	8	2		14.3	14.0	7	2	4	2
Hyco 1906	N=9	5.1		3.2					1.4		1.8				
	05P		3.6	3.3	9	-	-	-		2.8	2.6	9	-	-	-
October 1972 -	50P		4.5	3.0	9	-	-	-		4.9	4.3	6	3	-	-
July 1974	75N		5.0	3.6	9	-	-	-		1.8	2.0	9	-	-	-
	750N		5.3	4.5	6	3	-	-		1.6	2.1	9	-	-	-
	5P+75N		7.3	5.6	7	2	-	-		3.5	2.5	9	-	-	-
	50P+750N		30.0	7.5	-	1	6	2		28.9	9.5	-	1	5	3
Hyco 1116	N=7	3.7		2.4					2.8		3.6				
	05P		3.8	2.9	7	-	-	-		2.6	1.8	7	-	-	-
October 1972 -	50P		5.8	4.5	6	1	-	-		5.9	3.8	4	3	-	-
July 1974	75N		3.8	3.0	7	-	-	-		2.0	2.0	7	-	-	-
	750N		6.3	8.8	6	-	1	-		4.9	8.8	6	-	1	-
	5P+75N		5.2	3.2	7	-	-	-		2.7	2.7	7	-	-	-
	50P+750N		27.9	13.4	1	-	4	2		30.5	9.2	-	1	3	3

TABLE 13. GROWTH RESPONSE OF SELENASTRUM CAPRICORNUTUM IN LAKE SAMPLES, CONTROLS AND ON ADDITION OF NUTRIENT SPIKES OF NITROGEN AND PHOSPHORUS

Lake Station(s) Sample Period	Pretreatment Spike	Autoclaved Mean Growth mg/l Control	Spiked	S.D.	No. Responding, Growth Ranges 0-5	5.1-15	15.1-30	>30 mg/l	Filtered Mean Growth mg/l Control	Spiked	S.D.	No. Responding, Growth Ranges 0-5	5.1-15	15.1-30	>30 mg/l
James	N=7	2.0		2.2					0.6		0.5				
201, 206, 210, 212	05P		2.9	2.2	7	-	-	-		1.1	1.0	7	-	-	-
	50P		3.2	1.8	7	-	-	-		1.3	1.3	7	-	-	-
July 1971 -	75N		2.7	3.1	7	-	-	-		0.9	0.9	7	-	-	-
November 1973	750N		7.0	11.3	6	-	1	-		3.9	7.2	6	-	1	-
	5P+75N		3.8	2.3	7	-	-	-		1.9	1.2	7	-	-	-
	50P+750N		15.1	10.8	2	2	3	-		9.5	8.5	3	2	2	-
Rhodhiss	N=14	9.8		6.2					5.4		3.9				
3, 7, 9, 13, 1924,	05P		9.6	6.4	13	1	-	-		6.4	4.8	13	1	-	-
1778, 1836	50P		10.0	6.1	13	1	-	-		7.8	5.9	11	3	-	-
	75N		11.1	7.2	13	1	-	-		6.8	5.0	12	2	-	-
November 1971 -	750N		25.5	18.8	5	1	6	2		13.6	13.4	9	2	2	1
November 1973	5P+75N		12.1	6.2	12	2	-	-		7.0	5.0	13	1	-	-
	50P+750N		35.1	14.1	-	2	9	3		28.9	16.2	2	2	7	3
Hickory	N=5	9.9		6.2					0.8		1.2				
1542, 1632, 1489	05P		6.8	4.2	5	-	-	-		1.2	1.3	5	-	-	-
	50P		8.9	3.1	5	-	-	-		5.9	4.9	3	2	-	-
August 1971 -	75N		9.0	5.6	5	-	-	-		0.4	0.5	5	-	-	-
November 1973	750N		15.1	12.9	3	1	1	-		0.4	0.7	5	-	-	-
	5P+75N		11.3	5.7	5	-	-	-		1.9	1.5	5	-	-	-
	50P+750N		35.3	4.8	-	-	5	-		21.1	10.7	-	1	3	1
Lookout Shoals	N=4	8.5		9.5					2.8		3.3	4	-	-	-
1466, 1498, 1538	05P		8.1	10.5	4	-	-	-							
	50P		10.6	7.0	3	1	-	-		3.6	4.8	1	3	-	-
April 1972 -	75N		7.2	9.2	4	-	-	-		9.3	2.4	4	-	-	-
November 1973	750N		5.9	7.3	4	-	-	-		3.3	4.1	4	-	-	-
	5P+75N		10.3	9.6	3	1	-	-		3.3	4.3	3	1	-	-
	50P+750N		37.8	7.7	-	-	2	2		4.6	5.7	-	1	1	2

TABLE 14. GROWTH RESPONSE OF SELENASTRUM CAPRICORNUTUM IN LAKE SAMPLES, CONTROLS AND ON ADDITION OF NUTRIENT SPIKES OF NITROGEN AND PHOSPHORUS

Lake Station(s) Sample Period	Pretreatment Spike	Autoclaved Mean Growth mg/l Control	Spiked	S.D.	No. Responding, Growth Ranges 0-5	5.1-15	15.1-30	>30 mg/l	Filtered Mean Growth mg/l Control	Spiked	S.D.	No. Responding, Growth Ranges 0-5	5.1-15	15.1-30	>30 mg/l
Norman	N=11	1.3		1.6					0.5		1.2				
109, 116, 126, 1302	05P		2.8	2.9	10	1	-	-		1.1	1.4	11	-	-	-
DC 26, RM 10	50P		6.5	4.5	5	6	-	-		6.4	3.7	3	8	-	-
	75N		1.4	1.8	11	-	-	-		0.7	1.1	11	-	-	-
August 1971 -	750N		1.2	1.7	11	-	-	-		0.7	1.2	11	-	-	-
November 1973	5P+75N		3.2	2.2	11	-	-	-		1.3	1.3	11	-	-	-
	50P+750N		19.3	10.5	-	5	5	1		18.3	9.5	1	4	5	1
Mt. Island	N=12	0.4		0.5					0.1		0.1				
941, 960, 977	05P		1.3	1.4	12	-	-	-		0.6	1.0	12	-	-	-
	50P		4.1	2.9	8	4	-	-		4.5	2.6	7	5	-	-
July 1973 -	75N		1.1	1.5	12	-	-	-		0.5	0.7	12	-	-	-
January 1974	750N		1.3	1.5	12	-	-	-		0.3	0.4	12	-	-	-
	5P+75N		3.7	4.4	10	2	-	-		2.5	4.7	11	-	1	-
	50P+750N		15.9	3.4	-	5	7	-		14.5	6.0	1	5	6	-
Wylie	N=9	5.9		4.8					1.0		2.0				
789, 83, 831	05P		4.5	3.7	9	-	-	-		2.2	2.3	8	1	-	-
	50P		4.9	3.3	9	-	-	-		3.9	2.2	8	1	-	-
July 1973 -	75N		5.5	4.6	9	-	-	-		1.6	3.0	9	-	-	-
January 1974	750N		13.2	10.5	5	2	2	-		4.1	8.1	7	-	1	1
	5P+75N		6.2	4.6	9	-	-	-		2.5	2.3	9	-	-	-
	50P+750N		22.2	7.5	-	2	7	-		18.6	7.3	1	1	7	-
Wylie	N=13	5.8		4.6					2.3		3.8				
681, 708, 74, AC 22	05P		5.7	4.9	12	1	-	-		3.0	4.1	13	-	-	-
	50P		5.5	4.4	13	-	-	-		4.7	4.5	11	2	-	-
July 1973 -	75N		5.8	4.2	13	-	-	-		2.7	3.9	13	-	-	-
January 1974	750N		9.1	7.5	10	3	-	-		4.2	5.8	12	1	-	-
	5P+75N		6.7	4.5	13	-	-	-		3.5	4.0	12	1	-	-
	50P+750N		21.6	7.3	-	7	6	-		17.6	9.0	1	7	5	-

TABLE 15. GROWTH RESPONSE OF SELANASTRUM CAPRICORNUTUM IN LAKE SAMPLES, CONTROLS AND ON ADDITION OF NUTRIENT SPIKES OF NITROGEN AND PHOSPHORUS

Lake Station(s) Sample Period	Pretreatment Spike	Autoclaved Mean Growth mg/l Control	Spiked	S.D.	No. Responding, Growth Ranges 0-5	5.1-15	15.1-30	>30 mg/l	Filtered Mean Growth mg/l Control	Spiked	S.D.	No. Responding, Growth Ranges 0-5	5.1-15	15.1-30	>30 mg/l
Wylie	N=4	10.2		4.3					8.9		9.5				
SF 30	05P		8.6	3.9	4	-	-	-		9.7	9.3	4	-	-	-
	50P		9.7	3.2	4	-	-	-		11.0	8.3	4	-	-	-
July 1973 -	75N		10.0	5.4	4	-	-	-		13.7	16.6	3	-	1	-
January 1974	750N		27.4	8.1	-	1	3	-		15.6	17.5	3	-	1	-
	5P+75N		12.1	5.7	3	1	-	-		10.3	8.6	4	-	-	-
	50P+750N		32.6	6.4	-	-	4	-		34.4	13.1	-	-	4	-
Fishing Creek	N=3	28.9		4.6					20.1		5.6				
27, 31	05P		26.6	8.7	3	-	-	-		16.5	8.8	3	-	-	-
	50P		24.9	6.4	3	-	-	-		15.1	10.5	3	-	-	-
August 1971 -	75N		29.1	7.8	3	-	-	-		17.9	11.1	3	-	-	-
April 1972	750N		60.0	8.5	-	-	1	2		36.6	23.5	-	1	2	-
	5P+75N		28.9	6.9	3	-	-	-		18.7	9.0	3	-	-	-
	50P+750N		60.6	6.5	-	-	1	2		46.8	8.3	-	-	3	-
Wateree	N=15	11.1		9.5					5.6		7.0				
2, 58, 100, 104, 157	05P		7.8	7.5	15	-	-	-		4.5	4.9	15	-	-	-
	50P		7.9	7.3	15	-	-	-		6.5	4.8	12	3	-	-
August 1971 -	75N		9.7	8.1	15	-	-	-		5.8	6.4	14	-	1	-
January 1974	750N		21.6	15.9	8	2	5	-		11.7	14.4	10	2	3	-
	5P+75N		11.0	8.1	15	-	-	-		7.0	5.8	15	-	-	-
	50P+750N		31.0	9.8	1	2	11	1		30.1	8.5	1	1	9	4

TABLE 16. GROWTH RESPONSE OF SELENASTRUM CAPRICORNUTUM IN LAKE SAMPLES, CONTROLS AND ON ADDITION OF NUTRIENT SPIKES OF NITROGEN AND PHOSPHORUS

Lake Station(s) Sample Period	Pretreatment Spike	Autoclaved Mean Growth mg/l Control	Spiked	S.D.	No. Responding, Growth Ranges 0-5	5.1-15	15.1-30	>30 mg/l	Filtered Mean Growth mg/l Control	Spiked	S.D.	No. Responding, Growth Ranges 0-5	5.1-15	15.1-30	>30 mg/l
Kerr-Roanoke	N=8	12.1		11.5					4.2		5.9				
19, 24	05P		8.9	6.7	8	-	-	-		5.3	5.6	7	1	-	-
	50P		8.6	6.0	8	-	-	-		7.2	7.4	6	2	-	-
December 1971 -	75N		12.2	7.8	8	-	-	-		5.0	7.3	8	-	-	-
March 1974	750N		26.4	11.8	2	2	3	1		13.7	16.3	5	-	2	1
	5P+75N		12.7	8.5	8	-	-	-		6.5	6.7	8	-	-	-
	50P+750N		33.5	10.2	-	3	4	1		28.3	12.5	1	-	5	2
Kerr-Nutbush	N=11	12.4		13.1					4.7		9.9				
118, 1308	05P		10.8	12.0	10	1	-	-		4.0	10.5	11	-	-	-
	50P		13.2	12.6	9	2	-	-		4.3	9.7	11	-	-	-
January 1973 -	75N		12.9	12.3	10	1	-	-		5.6	11.3	11	-	-	-
May 1974	750N		32.7	17.0	2	1	6	2		14.6	18.6	5	3	3	-
	5P+75N		13.0	11.4	9	2	-	-		5.6	10.9	11	-	-	-
	50P+750N		35.9	16.8	1	1	6	3		22.6	18.9	2	3	4	2
Kerr-Nutbush	N=8	3.0		2.7					0.7		0.6				
111, 114	05P		3.3	3.0	8	-	-	-		8.0	0.8	8	-	-	-
	50P		5.9	6.3	6	2	-	-		1.8	1.6	8	-	-	-
January 1973 -	75N		3.6	4.0	8	-	-	-		0.9	0.9	8	-	-	-
May 1974	750N		8.6	12.9	6	1	-	1		4.6	8.9	7	-	1	-
	5P+75N		5.5	3.5	7	1	-	-		1.0	0.9	8	-	-	-
	50P+750N		28.9	6.7	-	-	6	2		19.9	13.8	-	2	2	4
Kerr-Nutbush	N=13	2.0		2.9					1.6		3.6				
103, 108	05P		1.7	1.9	13	-	-	-		2.0	3.5	13	-	-	-
	50P		6.0	3.4	9	4	-	-		7.3	7.2	7	5	1	-
September 1972	75N		2.3	4.4	12	1	-	-		1.7	4.0	13	-	-	-
May 1974	750N		4.3	9.3	11	1	1	-		5.3	12.5	11	-	1	1
	5P+75N		3.5	3.9	13	-	-	-		3.6	5.3	12	1	-	-
	50P+750N		25.9	8.1	-	1	9	3		23.8	10.6	1	1	8	3

TABLE 17. GROWTH RESPONSE OF SELENASTRUM CAPRICORNUTUM IN LAKE SAMPLES, CONTROLS AND ON ADDITION OF NUTRIENT SPIKES OF NITROGEN AND PHOSPHORUS

Lake Station(s) Sample Period	Pretreatment Spike	Autoclaved Mean Growth mg/l Control	Spiked	S.D.	No. Responding, Growth Ranges 0-5	5.1-15	15.1-30	>30 mg/l	Filtered Mean Growth mg/l Control	Spiked	S.D.	No. Responding, Growth Ranges 0-5	5.1-15	15.1-30	>30 mg/l
Kerr-Roanoke	N=19	5.8		6.0					1.4		1.8				
1, 2, 8	05P		6.8	6.8	16	3	-	-		2.4	3.0	18	1	-	-
	50P		9.7	7.2	13	5	1	-		5.6	6.4	13	4	2	-
July 1971 -	75N		6.2	6.4	18	1	-	-		1.8	2.4	19	-	-	-
May 1974	750N		8.0	9.6	17	1	1	-		5.6	13.3	17	-	-	2
	5P+75N		7.9	6.7	16	3	-	-		2.4	2.3	19	-	-	-
	50P+750N		28.1	12.6	-	2	14	3		20.8	14.3	4	3	6	6
Gaston	N=5	7.5		4.9					1.2		1.6				
82, 166, 324	05P		8.9	5.2	4	1	-	-		1.9	2.1	5	-	-	-
	50P		12.9	5.5	3	2	-	-		8.5	7.3	2	2	1	-
July 1971 -	75N		6.9	5.0	5	-	-	-		1.4	1.6	5	-	-	-
March 1974	750N		6.1	4.3	5	-	-	-		1.3	1.6	5	-	-	-
	5P+75N		8.4	4.7	5	-	-	-		1.8	1.9	5	-	-	-
	50P+750N		34.9	14.6	-	1	2	2		19.1	16.4	-	3	1	1
Roanoke Rapids	N=3	6.0		2.3					0.2		0.4				
2, 28, 56	05P		4.8	3.4	3	-	-	-		0.5	0.5	3	-	-	-
	50P		11.3	3.3	2	1	-	-		8.2	2.0	-	3	-	-
March 15, 1974	75N		3.1	2.7	3	-	-	-		0.1	0.2	3	-	-	-
	750N		2.7	2.9	3	-	-	-		0.1	0.1	3	-	-	-
	5P+75N		4.9	2.7	3	-	-	-		0.3	0.4	3	-	-	-
	50P+750N		33.2	1.4	-	-	3	-		12.4	12.9	-	1	2	-

TABLE 18. GROWTH RESPONSE OF SELENASTRUM CAPRICORNUTUM IN LAKE SAMPLES, CONTROLS AND ON ADDITION OF NUTRIENT SPIKES OF NITROGEN AND PHOSPHORUS

Lake Station(s) Sample Period	Pretreatment	Autoclaved							Filtered						
		Mean Growth mg/l			No. Responding, Growth Ranges				Mean Growth mg/l			No. Responding, Growth Ranges			
	Spike	Control	Spiked	S.D.	0-5	5.1-15	15.1-30	>30 mg/l	Control	Spiked	S.D.	0-5	5.1-15	15.1-30	>30 mg/l
Kerr Scott 3 Stations April 1974	N=6	3.0		1.5					0.3		0.3				
	05P		3.8	1.6	6	-	-	-		0.4	0.3	6	-	-	-
	50P		5.1	1.3	6	-	-	-		2.2	0.4	6	-	-	-
	75N		1.9	0.5	6	-	-	-		0.3	0.3	6	-	-	-
	750N		2.5	0.2	6	-	-	-		0.5	0.4	6	-	-	-
	5P+75N		3.1	0.5	6	-	-	-		0.6	0.5	6	-	-	-
	50P+750N		20.0	6.1	-	2	4	-		4.7	3.1	2	4	-	-
High Rock 594, 654, 750 April 4, 1974	N=6	11.8		9.0					4.0		5.8				
	05P		7.9	7.2	6	-	-	-		6.1	7.2	6	-	-	-
	50P		9.5	5.2	4	2	-	-		15.3	2.2	-	4	2	-
	75N		10.7	9.4	4	2				6.4	8.1	4	2		
	750N		25.4	12.9	-	4	2	-		6.2	8.5	4	2	-	-
	5P+75N		13.7	8.6	4	2	-	-		4.9	6.0	6	-	-	-
	50P+750N		35.5	8.8	-	-	6	-		16.0	12.4	2	-	4	-
Tuckertown 516, 548, 580	N=6	16.1		9.8					0.1		-				
	05P		16.4	8.0	6	-	-	-		0.1	-	6	-	-	-
	50P		20.7	2.9	4	2	-	-		15.0	1.2	-	4	2	-
	75N		14.9	10.5	6	-	-	-		0.1	-	6	-	-	-
	750N		15.8	10.0	6	-	-	-		0.3	0.4	6	-	-	-
	5P+75N		15.0	6.9	6	-	-	-		0.8	1.1	6	-	-	-
	50P+750N		37.3	6.7	-	-	6	-		13.1	10.8	2	2	2	-

TABLE 19. GROWTH RESPONSE OF SELENASTRUM CAPRICORNUTUM IN LAKE SAMPLES, CONTROLS AND ON ADDITION OF NUTRIENT SPIKES OF NITROGEN AND PHOSPHORUS

Lake Station(s) Sample Period	Pretreatment Spike	Autoclaved Mean Growth mg/l Control	Spiked	S.D.	No. Responding, Growth Ranges 0-5	5.-15	15.1-30	>30 mg/l	Filtered Mean Growth mg/l Control	Spiked	S.D.	No. Responding, Growth Ranges 0-5	5.1-15	15.1-30	>30 mg/l
Badin	N=6	9.8		5.2					6.0		0.4				
438, 458, 490	05P		12.5	2.6	4	2	-	-		1.0	3.2	6	-	-	-
	50P		18.7	4.1	2	2	2	-		18.2	1.5	-	-	6	-
April 5, 1974	75N		13.3	3.0	4	2	-	-		0.4	0.4	6	-	-	-
	750N		16.2	5.2	2	4	-	-		0.4	0.6	6	-	-	-
	5P+75N		11.0	1.2	4	2	-	-		0.4	0.6	6	-	-	-
	50P+750N		37.8	2.5	-	-	4	2		29.4	3.0	-	-	4	2
Tillery	N=14	13.1		9.5					1.9		1.6				
	05P		14.2	7.9	12	2	-	-		3.0	1.2	12	2	-	-
November 1971 -	50P		19.6	10.5	6	8	-	-		10.4	9.5	8	2	4	
April 1974	75N		13.0	9.8	12	2	-	-		2.0	1.7	14	-	-	-
	750N		14.5	11.9	12	2	-	-		2.0	1.7	14	-	-	-
	5P+75N		14.4	9.2	12	2	-	-		2.6	1.3	14	-	-	-
	50P+750N		30.3	15.5	2	2	10	-		13.6	13.5	8	-	4	2
Blewett Falls	N=6	10.7		2.6					0.8		1.0				
2, 26, 56	05P		14.4	3.2	4	2	-	-		2.4	1.8	6	-	-	-
	50P		18.5	0.2	2	4	-	-		16.8	2.2	-	2	4	-
April 9, 1974	75N		13.6	1.1	6	-	-	-		1.1	1.5	6	-	-	-
	750N		13.5	5.5	4	2	-	-		1.1	1.1	6	-	-	-
	5P+75N		13.0	5.8	4	2	-	-		1.5	1.4	6	-	-	-
	50P+750N		33.3	2.9	-	-	6	-		31.5	1.8	-	-	2	4

TABLE 20. GROWTH RESPONSE OF SELENASTRUM CAPRICORNUTUM IN LAKE SAMPLES, CONTROLS AND ON ADDITION OF NUTRIENT SPIKES OF NITROGEN AND PHOSPHORUS

Lake Station(s) Sample Period	Pretreatment	Autoclaved							Filtered						
		Mean Growth mg/l			No. Responding, Growth Ranges				Mean Growth mg/l			No. Responding, Growth Ranges			
	Spike	Control	Spiked	S.D.	0-5	5.1-15	15.1-30	>30 mg/l	Control	Spiked	S.D.	0-5	5.1-15	15.1-30	>30 mg/l
Tull, Davies, McKensie, Orton	N= 4	0.6		1.2					0.2		0.2				
	05P		4.1	7.4	3	-	1	-		0.6	0.6	4	-	-	-
	50P		6.1	9.2	3	-	1	-		1.0	0.9	4	-	-	-
	75N		4.6	7.0	3	-	1	-		1.5	2.4	4	-	-	-
	750N		3.3	4.2	3	-	1	-		0.4	0.3	4	-	-	-
	5P+75N		3.8	3.9	3	-	1	-		0.8	1.2	4	-	-	-
	50P+750N		14.3	3.8	-	3	1	-		13.0	4.2	-	2	2	-
Jackson, Black	N= 3	21.8		3.9					16.6		6.3				
	05P		18.6	5.7	3	-	-	-		14.4	4.7	3	-	-	-
	50P		19.1	5.4	3	-	-	-		15.8	5.5	3	-	-	-
	75N		20.3	6.1	3	-	-	-		16.5	4.8	3	-	-	-
	750N		34.9	8.3	-	3	-	-		24.8	2.9	-	3	-	-
	5P+75N		20.4	6.9	3	-	-	-		16.8	6.0	3	-	-	-
	50P+750N		34.8	8.0	-	2	1	-		28.9	0.6	-	2	1	-
Finches, Hodgins McNeils, Lytches Maccamaw	N= 7	2.9		2.7					1.2		1.3				
	05P		2.5	1.9	7	-	-	-		1.9	2.4	7	-	-	-
	50P		3.1	2.4	7	-	-	-		3.3	2.3	7	-	-	-
	75N		3.8	3.8	7	-	-	-		1.3	2.2	7	-	-	-
	750N		7.1	7.5	5	2	-	-		2.2	4.1	6	1	-	-
	5P+75N		6.9	9.8	6	-	1	-		5.3	8.1	5	1	1	-
	50P+750N		22.1	12.2	1	2	2	2		16.1	11.1	2	1	4	-
Monroe, Jones (JO) Salters, Singletary White	N= 5	0.3		0.4					0.3		0.4				
	05P		0.6	0.4	5	-	-	-		0.5	0.5	5	-	-	-
	50P		1.3	1.1	5	-	-	-		0.9	0.8	5	-	-	-
	75N		1.0	1.6	5	-	-	-		0.4	0.4	5	-	-	-
	750N		0.6	0.4	5	-	-	-		0.5	0.4	5	-	-	-
	5P+75N		0.7	0.5	5	-	-	-		0.5	0.5	5	-	-	-
	50P+750N		5.8	8.6	4	-	1	-		2.0	1.5	5	-	-	-

TABLE 21. GROWTH RESPONSE OF SELENASTRUM CAPRICORNUTUM IN LAKE SAMPLES, CONTROLS AND ON ADDITION OF NUTRIENT SPIKES OF NITROGEN AND PHOSPHORUS

Lake, Station(s) Sample Period	Pretreatment	Autoclaved							Filtered						
		Mean Growth mg/l			No. Responding, Growth Ranges				Mean Growth mg/l			No. Responding, Growth Ranges			
	Spike	Control	Spiked	S.D.	0-5	5.1-15	15.1-30	>30 mg/l	Control	Spiked	S.D.	0-5	5.1-15	15.1-30	>30 mg/l
Jones (JP)	N=1	0.4		-					0.0		-				
	05P		15.3	-	-	-	1	-		0.0	-	1	-	-	-
	50P		59.6	-	-	-	-	1		45.7	-	-	-	-	1
	75N		6.8	-	-	1	-	-		1.0	-	1	-	-	-
	750N		11.5	-	-	1	-	-		0.2	-	1	-	-	-
	5P+75N		5.1	-	-	1	-	-		0.2	-	1	-	-	-
	50P+750N		65.3	-	-	-	-	1		32.9	-	-	-	-	1
Johns	N=1	4.1							0.9		-				
	05P		3.6	-	1	-	-	-		0.0	-	1	-	-	-
	50P		2.9	-	1	-	-	-		1.2	-	1	-	-	-
	75N		8.9	-	1	-	-	-		4.2	-	1	-	-	-
	750N		48.2	-	-	-	-	1		35.1	-	-	-	-	1
	5P+75N		5.5	-	1	-	-	-		4.2	-	1	-	-	-
	50P+750N		43.7	-	-	-	-	1		34.5	-	-	-	-	1
Crystal	N=1	53.6		-					30.6		-				
	05P		50.0	-	1	-	-	-		24.1	-	1	-	-	-
	50P		51.7	-	1	-	-	-		19.5	-	1	-	-	-
	75N		53.2	-	1	-	-	-		28.6	-	1	-	-	-
	750N		96.0	-	1	-	-	1		66.7	-	-	-	-	1
	5P+75N		59.0	-	1	-	-	-		24.9	-	1	-	-	-
	50P+750N		88.4	-	-	-	-	1		56.1	-	-	-	1	-
Mattamuskeet, Phelps	N=2	0.1		-					0.1		-				
	05P		.45	.49	2	-	-	-		0.1	-	2	-	-	-
	50P		2.8	1.3	2	-	-	-		6.9	3.8	1	1	-	-
	75N		0.1	-	2	-	-	-		0.1	-	2	-	-	-
	750N		0.15	0.1	2	-	-	-		0.1	-	-	-	-	-
	5P+75N		0.2	0.1	2	-	-	-		0.1	-	-	-	-	-
	50P+750N		15.5	16.5	1	-	1			6.6	6.6	1	1	-	-

nutrients. The second is the relationship of the indicated nutrient limitation and the original raw water composition with respect to quantities of nitrogen and phosphorus.

To examine the first relationship sets of samples from series of lakes or subsets of stations within lakes were assembled in Tables 22-25. Each of the tables has been arranged according to a geographical or hydrologic pattern. For example those lakes in Table 22 represents the series of impoundments on the Catawba River from Lake James downstream to Wateree Lake a distance of over 200 river miles. The data in the tables includes the mean control growth of the samples tested, their standard deviation for each of the pretreatment sets and correlation coefficients, significant at the 95% level, between the control growth and the quantities of soluble nutrients found in the sample after the indicated pretreatment.

The use of autoclaving as a pretreatment with consequent solubilization produces higher nutrient levels and the inevitable greater control biomass. There was no instance in which the autoclaved growth was less than that of samples filtered as pretreatment although in one or two instances it was approximately the same due to very marginal growth in both. Only where the correlation was significant at 95% or greater is the actual coefficient (r) value shown. Thus, as shown in Table 22 for Lake James, of the 7 samples tested when related to the nutrient levels, following pretreatment, no significant correlations were found. However, in Lake Rhodhiss it is evident that good correlations were found in both autoclaved and filtered samples with the phosphorus component of the water and in the filtered sample with the quantity of ammonia that was present. In this series of impoundments of the Catawba River, it is apparent that the enrichment from municipal and industrial wastes entering Lake Wylie as well as further downstream results in stronger correlations as well as correlations with different nutrient species. It would appear that the correlation between biomass formed by the seeded alga and the quantity of nutrient improves as nutrient levels increase, probably due in part to improvement in precision of measurements.

This observation was confirmed by the assay data derived from the waters of the two arms of the John H. Kerr Reservoir, Table 23. Strong correlations between control growth and nutrients were evident in the section of the lake noted as Kerr-Nutbush. In downstream station sequence there was an indication of a shift from good correlations with nitrogen and phosphorus, Stations 118 and 1308, to a solely phosphorus correlated response at Stations 108 and 103. This paralleled the downstream decrease in nutrient concentrations.

Occasionally, such as the waters from Roanoke Rapids, Table 23 and Badin and Tuckerton, Table 24, negative correlations were found which were at the 95% significant level. The meaning of these negative relationships is not clear. Omission of correlations from these tables may also mean too few samples were available for a correlation analysis.

Nitrogen and Phosphorus Limitation

Using the data presented in Tables 11-21 an estimate was made as to whether the particular set of waters was phosphorus limited, nitrogen limited, or limited by both nutrients. This was determined for autoclaved and filtered samples. The

TABLE 22. CORRELATIONS OF SEEDED CONTROL GROWTH AND NUTRIENT CONCENTRATIONS FOLLOWING PRE-TREATMENTS

Lake and Stations	Samples Tested	Treat-ment	Control Growth*	S.D.	Corr. Coef. (r) P≥ .05 NH_3	NO_2NO_3	PO_4-P	Total-P
James								
201, 206, 210, 212	7	A	2.0	2.2	-	-	-	-
		F	0.6	0.5	-	-	-	-
Rhodhiss	14	A	9.8	6.3	-	-	.7169	.6770
3, 7, 9, 13, 1724, 1778, 1836		F	5.4	3.9	.5334	-	-	.6080
Hickory	5	A	9.9	6.2	-	-	-	-
1542, 1632, 1689		F	0.8	1.2	-	-	-	-
Lookout Shoals	4	A	8.4	9.5	-	-	-	.9802
1466, 1498, 1538		F	2.8	3.3	-	-	.9719	-
Norman	11	A	1.3	1.6	-	-	-	-
109, 116, 126, 1302, DC26, RM10		F	0.6	1.2	-	-	-	-
Mt. Island	12	A	0.4	0.5	-	-	-	.6356
960, 977, 941		F	0.1	0.1	-	-	-	-
Wylie	9	A	5.9	4.8	-	.9479	.6891	-
83, 831, 789		F	1.0	2.0	-	-	.7910	.9331
681, 708, 74, AC22	13	A	5.8	4.6	-	.7934	.8767	.7190
		F	2.3	3.8	-	-	.7388	.8451
SF 30	4	A	10.2	4.3	-	-	-	-
		F	8.9	9.5	-	-	.9335	.9504
Fishing Creek	3	A	28.9	4.6	-	-	-	-
27, 31		F	20.1	5.6	-	-	-	.9899 (P≥.10)
Wateree	15	A	11.1	9.5	-	.9177	.8359	.6691
2, 58, 100, 104, 157		F	5.7	7.1	.8012	.8454	.8004	.6703

*Average of all samples, mg/l.

TABLE 23. CORRELATIONS OF SEEDED CONTROL GROWTH AND NUTRIENT CONCENTRATIONS FOLLOWING PRE-TREATMENTS

Lake and Stations	Samples Tested	Treat-ment	Control Growth*	S.D.	Corr. Coef. (r) P> .05			
					NH_3	NO_2NO_3	PO_4-P	Total-P
Kerr-Roanoke	8	A	12.2	11.5	-	-	-	-
19, 24,		F	4.2	5.9	-	-	.6617	.7455
8, 2, 1	19	A	5.8	6.0	-	-	-	-
		F	1.4	1.8	-	.5517	-	-
Kerr-Nutbush	11	A	12.4	13.1	.7347	.7791	-	-
118, 1308		F	4.7	9.9	-	.6049	.6548	.6313
114, 11	8	A	3.0	2.7	-	.8633	-	.7833
		F	0.7	0.6	-	-	.6579 ($P \geq .10$)	-
108, 103	13	A	2.0	2.9	-	-	.7561	.7138
		F	1.6	3.6	-	-	.9641	.9604
Gaston	5	A	7.5	4.9	-	-	-	-
82, 166, 324		F	1.2	1.6	-	-	-	-
Roanoke Rapids	4	A	6.0	2.3	-	-	-	-.9566
		F	0.2	0.4	-	-	-	-
Chowan River	17	A	4.3	3.1	-	-	-	-
13, 17, CO1, SW1		F	1.9	2.3	-	-	-	-
AL, RO45	8	A	2.3	2.0	-	-	.7052	-
		F	1.1	1.5	.7755	-	-	-

*Average of all samples, mg/1.

possibility, therefore, was one of three conditions of nutrient limitation following two pretreatment procedures. The results of all algal assays for all bodies of water, or stations within a particular lake, are presented in a set of tables for each specific nutrient limitation and pretreatment, Tables 26-31. The information assembled in these data sets includes mean control growth, the correlation coefficients with mean nutrient levels in the treated samples, the original mean lake quality with reference to inorganic nitrogen, PO_4-phosphorus, soluble-phosphorus and total-phosphorus and the ratio of inorganic-N to soluble-P. Thus in Table 26, 104 water samples taken from 11 different lakes or stations have been shown to be phosphorus limited. The control growth in these samples, mean values, ranged from as low as 0.1 mg/1 to as high as 16.1 mg/1. Where control growth was reasonably high the correlation coefficient was positive to the nutrient quantities in the pretreated water and showed in four instances to be significant to total-P, in two instances to PO_4-P and one instance to NO_2+NO_3 and

TABLE 24. CORRELATIONS OF SEEDED CONTROL GROWTH AND NUTRIENT CONCENTRATIONS FOLLOWING PRE-TREATMENTS

Lake and Stations	Samples Tested	Treat-ment	Control Growth*	S.D.	Corr. Coef. (r) P≥ .05 NH_3	NO_2NO_3	PO_4-P	Total-P
Kerr Scott	6	A	3.0	1.6	-	-	.9294	-
2566, 2610, 2628		F	0.3	0.3	.8910	-	-	-
High Rock	6	A	11.8	9.0	-	.8632	-	-
594, 654, 750		F	4.0	5.8	-	-	.9607	.9017
Tuckertown	6	A	16.1	9.8	-.8411	.9075	-	-.8705
516, 548, 580		F	0.1	-	-	-	-	-
Badin	6	A	9.8	5.2	-	-	-	-
438, 458, 490		F	0.5	0.4	-.9026	.8660	-.8660	-.8660
Tillery	14	A	13.2	9.4	-	.9519	.5699	-
3, 11, 18, 22, 268, 300, 344								
Blewett Falls	6	A	10.7	2.6	.8130	-	.9281	.8744
2, 26, 56		F	0.8	1.0	-	.8537	-	-

*Average of all samples, mg/l.

ammonia nitrogen. In one case the correlation to ammonia was high but negative.

Original lake quality showed a wide range of nutrient levels. Inorganic nitrogen was as low as 56 mg/m^3 and as high as 1245 mg/m^3. Soluble phosphorus ranged from 6 mg/m to 84 mg/m^3. Following pretreatment by filtration, Table 27, a considerably larger number of assayed samples were found to be phosphorus limited, in this instance 191 from 21 different lakes or stations. It is noteworthy that fewer autoclaved samples showed phosphorus limitation than the same samples following filtration pretreatment. It might be concluded that autoclaving solubilized sufficient quantity of phosphorus so that phosphorus limitation for algal growth was masked. Of the 191 samples that showed phosphorus limitation following filtration pretreatment there was no clear indication that the correlation between growth and nutrient levels in the non-spiked waters was predominately to phosphorus or nitrogen. The evidence would appear to be evenly divided.

The waters assayed to be nitrogen limited after autoclaving pretreatment showed that of 132 samples from 17 sets of lakes or lake stations six were highly correlated to the nitrogen quantity in the treated sample whereas nine were positively phosphorus correlated and one negatively correlated to phosphorus (Table 28). Where the pretreatment was by filtration 69 assays in 10 sample sets were nitrogen limited. Of these four were correlated to the soluble

TABLE 25. CORRELATIONS OF SEEDED CONTROL GROWTH AND NUTRIENT CONCENTRATIONS FOLLOWING PRE-TREATMENTS

Lake and Stations	Samples Tested	Treat-ment	Control Growth*	S.D.	Corr. Coef. (r) P≥ .)% NH_3	NO_2NO_3	PO_4-P	Total-P
Jackson, Black	3	A	21.8	3.9	-	-	-	-.9958
		F	16.6	6.3	-	-	-	-
Mattamuskeet, Phelps	2	A	0.1	0.0	-	-	-	-
		F	0.1	0.0	-	-	-	-
Tull, Davies, McKensie Orton	4	A	0.6	1.1	-	-	-	-
		F	0.2	0.2	-	-	-	-
Finches, Hodgins McNeils, Lytches Waccamaw	7	A	2.9	2.7	-	-	.9389	-
		F	1.2	1.3	-	.7642	.8876	-
Monroe, Jones(JO) Salters, Singletary, White	5	A	0.3	0.4	-	-	.9593	-
		F	0.3	0.4	-	-	-	-
Jones (JP)	1	A	0.4	-	-	-	-	-
		F	0.2	-	-	-	-	-
Johns	1	A	4.1	-	-	-	-	-
		F	0.9	-	-	-	-	-
Crystal	1	A	53.6	-	-	-	-	-
		F	30.6	-	-	-	-	-
University	20	A	9.2	10.7	-	-	.7663	.7555
		F	3.1	3.6	-	-	.7911	-
Michie	17	A	4.4	3.9	-	-	-	-
		F	2.8	2.4	-	.7911	-	-
Belews 1906	15	A	1.8	1.8	-	-	-	-
		F	1.2	1.1	-	-	-	-
1116	16	A	2.6	1.7	-	-	-	-
		F	1.2	1.2	-	-	-	-
Hyco 1906	9	A	5.1	3.2	-	-	-	-
		F	1.4	1.8	-	.7132	-	.7173
1116	7	A	3.7	2.4	-	-	-	.8708
		F	2.8	3.6	-	-	-	-

*Average of all samples, mg/l.

TABLE 26. CORRELATION OF GROWTH IN NON-SPIKED SAMPLES OF PHOSPHORUS LIMITED WATERS, AUTOCLAVED PRETREATMENT, WITH SAMPLE NUTRIENTS AND COMPARISON TO ORIGINAL LAKE NUTRIENT CONCENTRATIONS

Lake or Lake Station	No. of Samples Assayed	Control Growth*	Corr. Coef. (r) P≥.05				Mean Values Original Lake Quality mg/m³				Ratio
			NH_3	NO_2NO_3	PO_4-P	Sol-P	Inorg-N	PO_4-P	Sol-P	T-P	Inorg-N/Sol-P
Belews 1906	15	1.8	-	-	-	-	56	7	12	25	4.6
Belews 1116	15	2.6	-	-	-	-	90	6	8	20	11.2
Norman	11	1.3	-	-	-	-	139	6	6	11	23.1
Mt. Island	12	0.4	-	-	-	.6356	137	6	7	12	19.6
Gaston	5	7.5	-	-	-	-	281	10	22	28	12.8
Michie	17	4.4	-	-	-	-	238	9	17	28	14.0
Tuckertown	6	16.1	-.8411	.9075	-	.8705	742	5	38	120	19.5
Tillery	14	13.2	-	-	.6214	.5786	546	43	84	88	6.5
Blewett Falls	6	10.7	.8130	-	.9281	.8744	395	7	26	63	15.2
Jones (JP)	1	0.4	-	-	-	-	1245	5	10	20	124.5
Mattamuskeet, Phelps	2	0.1	-	-	-	-	97	5	6	33	16.2

*Biomass, mg/l 14 days growth of S. capricornutum in non-spiked water.

TABLE 27. CORRELATION OF GROWTH IN NON-SPIKED SAMPLES OF PHOSPHORUS LIMITED WATERS, FILTERED PRETREATMENT, WITH SAMPLE NUTRIENTS AND COMPARISON TO ORIGINAL LAKE NUTRIENT CONCENTRATIONS

Lake or Lake Station	No. of Samples Assayed	Control Growth*	Corr. Coef. (r) P≥.05				Mean Values Original Lake Quality mg/m³				Ratio
			NH_3	NO_2NO_3	PO_4-P	Sol-P	Inorg-N	PO_4-P	Sol-P	T-P	Inorg-N/Sol-P
Belews 1906	15	1.2	-	-	-	-	56	7	12	25	4.6
1116	15	1.2	-	-	-	-	90	6	8	20	11.2
Hyco 1906	9	1.4	-	.7132	-	.7173	156	7	11	19	14.2
1116	7	2.8	-	-	-	-	111	6	10	19	11.1
Hickory	5	0.8	-	-	-	-	177	8	13	38	13.6
Lookout Shoals	4	2.8	-	-	.9719	-	177	8	13	38	13.6
Norman	11	0.6	-	-	-	-	139	6	6	11	23.1
Mt. Island	12	0.1	-	-	-	-	137	6	7	12	19.6
Kerr (1, 2, 8)	19	1.4	-	.5517	-	-	127	7	16	20	7.9
Gaston	5	1.2	-	-	-	-	281	10	22	28	12.8
Roanoke Rapids	4	0.2	-	-	-	-	303	5	19	34	15.9
University	20	3.1	-	-	.7911	-	144	10	14	35	10.3
Michie	17	2.8	-	.7911	-	-	238	9	17	28	14.0
Chowan (13,17,CO 1,SW 1)	17	1.9	-	-	-	-	200	15	36	80	5.6
Hich Rock	6	4.0	-	-	.9607	.9017	751	11	60	115	12.5
Tuckertown	6	0.1	-	-	-	-	742	5	38	120	19.5
Badin	6	0.5	-.9026	.8660	-.8660	-.8660	750	20	40	102	18.7
Tillery	14	1.9	-	.9519	.5699	-	546	43	84	88	6.5
Blewett Falls	6	0.8	-	.8537	-	-	395	7	26	63	15.2
Jones (JP)	1	0.0	-	-	-	-	1245	5	10	20	124.5
Mattamuskeet, Phelps	2	0.1	-	-	-	-	97	5	6	33	16.2

*Biomass, mg/l 14 days growth of S. capricornutum in non-spiked water.

TABLE 28. CORRELATION OF GROWTH IN NON-SPIKED SAMPLES OF NITROGEN LIMITED WATERS, AUTOCLAVED PRETREATMENT, WITH SAMPLE NUTRIENTS AND COMPARISON TO ORIGINAL LAKE NUTRIENT CONCENTRATIONS

Lake or Lake Station	No. of Samples Assayed	Control Growth*	Corr. Coef. (r) P≥.05				Mean Values Original Lake Quality mg/m³				Ratio
			NH_3	NO_2NO_3	PO_4-P	Sol-P	Inorg-N	PO_4-P	Sol-P	T-P	Inorg-N/Sol-P
Hyco 1906	9	5.1	-	-	-	-	156	7	11	19	14.2
Rhodhiss	14	9.8	-	-	.7169	.6770	148	39	45	69	3.3
Hickory	5	9.9	-	-	-	-	177	8	13	38	13.6
Wylie (789, 83, 831)	9	5.9	-	.9479	.6891	-	206	14	25	31	8.2
Wylie (681, 708, 74, AC22)	13	5.8	-	.7934	.8767	.7190	158	8	13	21	12.1
Wylie (SF 30)	4	10.2	-	-	-	-	206	23	34	78	6.1
Fishing Creek (27, 31)	3	28.9	-	-	-	-	450	81	120	135	3.7
Wateree (2,58,100,104,137)	15	11.1	-	.9177	.8359	.6691	217	15	25	49	8.7
Kerr (19, 24)	8	12.2	-	-	-	-	168	7	14	35	12.0
Kerr (118, 1308)	11	12.4	.7347	.7791	-	-	142	24	37	108	3.8
Chowan (13, 17, O 1, SW 1)	17	4.3	-	-	-	-	200	15	36	80	5.6
(A1, Ro 45)	8	2.3	-	-	.7052	-	130	8	20	42	6.5
High Rock	6	9.0	-	.8632	-	-	751	11	60	115	12.5
Johns	1	4.1	-	-	-	-	170	165	195	250	0.9
Jackson, Black	3	21.8	-	-	-	-.9958	752	50	115	170	6.5
Monroe, Jones (JO) Singletary, Salters, White	5	0.3	-	-	.9593	-	57	5	13	17	4.3
Crystal	1	53.6	-	-	-	-	900	250	390	410	2.3

*Biomass, mg/l 14 days growth of S. capricornutum in non-spiked water.

TABLE 29. CORRELATION OF GROWTH IN NON-SPIKED SAMPLES OF NITROGEN LIMITED WATERS FILTERED PRETREATMENT, WITH SAMPLE NUTRIENTS AND COMPARISON TO ORIGINAL LAKE NUTRIENT CONCENTRATIONS

Lake or Lake Station	No. of Samples Assayed	Control Growth*	Corr. Coef. (r) P≥.05				Mean Values Original Lake Quality mg/m^3				Ratio
			NH_3	NO_2NO_3	PO_4-P	Sol-P	Inorg-N	PO_4-P	Sol-P	T-P	Inorg-N/Sol-P
Rhodhiss	14	5.4	.5334	-	-	.6080	148	39	45	69	3.3
Wylie (789, 83, 831)	9	1.0	-	-	.7910	.9331	206	14	25	31	8.2
Wylie (SF 30)	4	8.9	-	-	.9335	.9504	206	23	34	78	6.1
Fishing Creek	3	20.1	-	-	-	.9899 (P≥.10)	450	81	120	135	3.7
Wateree	15	5.7	.8012	.8454	.8004	.6703	217	15	25	49	8.7
Kerr (19, 24)	8	4.2	-	-	.6617	.7455	168	7	14	35	12.0
Kerr (118, 1308)	11	4.7	-	.6049	.6548	.6313	142	24	37	108	3.8
Johns	1	0.9	-	-	-	-	170	165	195	250	0.9
Jackson, Black	3	16.6	-	-	-	-	752	50	115	170	6.5
Crystal	1	30.6	-	-	-	-	900	250	390	410	2.3

*Biomass, mg/l 14 days growth of S. capricornutum in non-spiked water.

TABLE 30. CORRELATION OF GROWTH IN NON-SPIKED SAMPLES OF PHOSPHORUS & NITROGEN LIMITED WATERS, AUTOCLAVED PRETREATMENT, WITH SAMPLE NUTRIENTS AND COMPARISON TO ORIGINAL LAKE NUTRIENT CONCENTRATIONS

Lake or Lake Station	No. of Samples Assayed	Control Growth*	Corr. Coef. (r) P=.05				Mean Values Original Lake Quality mg/m³				Ratio
			NH_3	NO_2NO_3	PO_4-P	Sol-P	Inorg-N	PO_4-P	Sol-P	T-P	Inorg-N/Sol-P
Hyco 1116	7	3.7	-	-	-	.8708	111	6	10	19	11.1
James	7	2.0	-	-	-	-	87	6	7	18	12.4
Lookout Shoals	4	8.4	-	-	-	.9802	177	8	13	38	13.6
Kerr (111, 114)	8	3.0	-	.8633	-	.7833	80	7	7	23	11.4
Kerr (103, 108)	13	2.0	-	-	.7561	.7138	79	7	9	19	8.8
Kerr (1, 2, 8)	19	5.8	-	-	-	-	127	7	16	20	7.9
Roanoke Rapids (2, 28, 56)	4	6.0	-	-	-	-.9566	303	5	19	34	15.9
University	20	9.2	-	-	.7663	.7555	144	10	14	35	10.3
Kerr Scott	6	3.0	-	-	.9294	-	282	5	22	47	12.8
Badin	6	9.8	-	-	-	-	750	20	40	102	18.7
Tull, Davies, Orton, McKensie	4	0.6	-	-	-	-	334	63	70	105	4.8
Finches, Hodgins, McNeils Lytches, Waccamaw	7	2.9	-	-	.9389	-	253	15	28	42	9.0

*Biomass, mg/l 14 days growth S. capricornutum in non-spiked water.

TABLE 31. CORRELATION OF GROWTH IN NON-SPIKED SAMPLES OF PHOSPHORUS & NITROGEN LIMITED WATERS, FILTERED TREATMENT, WITH SAMPLE NUTRIENTS AND COMPARISON TO ORIGINAL LAKE NUTRIENT CONCENTRATIONS

Lake or Lake Station	No. of Samples Assayed	Control Growth*	Corr. Coef. (r) $P \geq .05$				Mean Values Original Lake Quality mg/m^3				Ratio
			NH_3	NO_2NO_3	PO_4-P	Sol-P	Inorg-N	PO_4-P	Sol-P	T-P	Inorg-N/Sol-P
James	7	0.6	-	-	-	-	87	6	7	18	12.4
Wylie (681, 708, 74, AC 22)	13	2.3	-	-	.7388	.8451	158	8	13	21	12.1
Kerr (111, 114)	8	0.7	-	-	.6579	-	80	7	7	23	11.4
Kerr (103, 108)	13	1.6	-	-	.9641	.9604	79	7	9	19	8.8
Chowan (A1, RO 45)	8	1.1	.7755	-	-	-	130	8	20	42	6.5
Kerr Scott	6	0.3	.8910	-	-	-	282	5	22	47	12.8
Tull, Davies, Orton, McKensie	4	0.2	-	-	-	-	334	63	70	105	4.8
Finches, Hodgins, McNeils Lytches, Waccamaw	7	1.2	-	.7642	.8876	-	253	15	28	42	9.0
Monroe, Jones (JO) Singletary, Salters, White	5	0.3	-	-	-	-	57	5	13	17	4.4

*Biomass, mg/l 14 days growth of S. capricornutum in non-spiked water.

nitrogen component of the filtered sample and 12 were highly correlated at a significant level to the soluble phosphorus components, (Table 29) of twelve autoclaved sampling sets, one correlated to both nitrogen and phosphorus, nine were correlated to soluble phosphorus while only one showed a significant correlation to soluble nitrogen and one was negatively correlated to soluble phosphorus (Table 30). In the samples pretreated by filtration 71 in nine sets were phosphorus and nitrogen limited with three correlated to the soluble nitrogen and six to the soluble phosphorus components (Table 31).

These results can be summarized in two ways. In one, shown in Table 32, the mean control growth of each of the set of samples that were phosphorus, nitrogen or phosphorus and nitrogen limited following the two pretreatment procedures has been correlated to the original lake nutrient quality, specifically the soluble nitrogen and phosphorus components and the ratio of these two. In this presentation the actual (r) value derived from the correlation determinations is shown without noting a level of significance. The r values which are less than .5 are generally assumed to be of little or no significance. It is evident that autoclaving as a pretreatment resulted in

TABLE 32. RELATIONSHIP OF CONTROL GROWTH, SEEDED SELENASTRUM CAPRICORNUTUM IN AUTOCLAVED AND FILTERED WATERS AND NUTRIENT LEVELS OF ORIGINAL RAW WATER

Nutrient Limitation Based on Response to Spikes	N	Corr. Coef. (r) Inorg-N	Soluble P	Ratio N/P
Phosphorus				
Autoclaved	11	.3151	.7928	-.2992
Filtered	45	-.3844	-.2380	-.3565
Nitrogen				
Autoclaved	17	.7653	.8270	-.2932
Filtered	10	.9103	.7439	.4720
Phosphorus and Nitrogen				
Autoclaved	12	.4172	-.1344	-.0067
Filtered	9	-.2331	-.3693	.3042

control growths in the phosphorus limited series that was highly correlated to the original soluble phosphorus level, an r value of .7928. All other correlations were at nonsignificant levels. In contrast the nitrogen limited samples following both autoclaved and filtered pretreatment showed unusually

high correlations to both the inorganic nitrogen as well as soluble phosphorus of the original lake quality. Samples limited in both phosphorus and nitrogen, whether autoclaved or filtered as pretreatment, showed correlations with neither of the soluble nitrogen or phosphorus components of the original lake water. It would thus appear that this particular analysis did not discriminate in any consistent manner between the two pretreatment procedures to indicate whether one or the other was preferable in relating the response of the algal assay growth to the quality of the original lake water.

Nutrient Limitation and Original Lake Quality

In the second overall summary, Table 33, the mean value for all autoclaved and filtered samples for each of the limitation series, phosphorus, nitrogen, and phosphorus and nitrogen are compared to the mean values of the original lake water nutrient concentrations. A clear growth limitation relationship emerges, regardless of the limiting nutrient, in the autoclaved pretreated samples but not in the filtered samples. This would be expected. It also shows that those samples that were nitrogen limited, whether autoclaved or filtered, had an average growth which was greater than either the phosphorus limited or phosphorus and nitrogen limited samples. When these summary data are compared to the mean values of the original lake water nutrient levels it is clear that the phosphorus limited samples had at least a soluble phosphorus component of about 23 mg/m^3 with a mean ratio of nitrogen/phosphorus of about 14. Nitrogen limited samples averaged considerably higher in mean soluble phosphorus, 3-5 times, depending on whether the sample was autoclaved or filtered but the nitrogen/phosphorus ratio was lower in the range of 5-7 for the two pretreatment procedures. Phosphorus and nitrogen limited samples showed soluble phosphorus about the same as for the phosphorus limited but nitrogen was considerably the lowest on the average and the ratio of soluble nitrogen to soluble phosphorus was in the range of 9-11.

TABLE 33. NUTRIENT LIMITATION OF ALGAL ASSAYED SAMPLES, CONTROL BIOMASS AND ORIGINAL LAKE NUTRIENT QUALITY

Nutrient Limitation	Pre-Treatment	No. of Assays	Mean Control Biomass, mg/l	Mean Values Original Lake Nutrients mg/m^3 Inorg-N	PO_4-P	Sol-P	T-P	Mean Ratios Inorg-N/Sol-P
Phosphorus	Autoclaved	104	5.31	360	9.9	21.4	40.7	24.3
			(5.81)	(272)	(10.4)	(22.6)	(42.8)	(14.3)
	Filtered	191	1.37	326	9.8	22.3	45.1	18.6
			(1.37)	(281)	(10.1)	(22.9)	(46.4)	(13.3)
Nitrogen	Autoclaved	132	12.15	293	42.9	68.5	98.1	7.3
	Filtered	69	9.81	335	66.8	100.0	133.5	5.5
Phosphorus and Nitrogen	Autoclaved	105	4.70	227	13.3	21.3	41.8	11.4
	Filtered	71	0.92	162	13.8	21.0	37.1	9.1

( ) mean values with Jones Pond (JP) deleted because of unusual nitrogen concentration.

SECTION VIII

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APPENDIX A. SEASONAL MEAN VALUES OF LIMNOLOGICAL PARAMETERS, LAKE SAMPLES USED IN ALGAL ASSAYS

Lake	(9) Belews 1116		(9) Belews 1906		(10) Hyco 1116		(10) Hyco 1906	
Season	Apr.-Nov.	Dec.-March	Apr.-Nov.	Dec.-March	Apr.-Nov.	Dec.-March	Apr.-Nov.	Dec.-March
No. of Samples	9	5	9	5	5	2	6	2
Water Temp. °C	21.9	8.4	18.9	8.6	20.5	11.6	22.6	13.5
Secchi Depth-m	2.0	1.9	2.3	2.1	0.7	0.7	1.5	0.7
NH_3-N	20	131	38	125	44	55	56	45
NO_2+NO_3-N	36	98	52	80	67	115	100	128
Inorg-N	56	226	90	205	111	170	156	173
Kjel-N	277	360	296	220	416	225	193	185
Total-N	313	458	348	300	483	340	293	313
PO_4-P	6.7	6.6	6.2	54	6.0	7.5	6.6	7.5
T-Soluble P	11.7	8.3	7.7	11.6	10.2	15.0	10.8	15.0
T-Particulate P	13.5	11.0	13.6	1.0	9.0	250	9.8	70.0
Total P	24.6	19.6	20.4	13.6	19.2	40.0	18.8	85.0
TN/TP	20.5	25.9	28.8	23.8	28.4	8.6	16.0	6.2
Phyto. Cell Density no./ml	4237(7)	698	1435(6)	734	1564	2571	2058	2029
Chlor a Turner Units	14(4)	10(1)	14(4)	9(1)	18(2)	23	19(4)	23
Productivity mgC/m^3/hr.	13(5)	12(2)	9(5)	9(2)	21(3)	23	18(4)	18

	(11) University		(12) Michie	
No. of Samples	12	7	12	5
Water Temp. °C	23.3	8.4	23.3	7.9
Secchi Depth-m	1.0	0.5	1.0	0.4
NH_3-N	86	106	60	110
NO_2+NO_3-N	58	297	178	398
Inorg-N	144	403	238	508
Kjel-N	541	510	540	397
Total-N	600	820	7.18	795
PO_4-P	10.2	17.1	9.0	14.0
T-Soluble P	14.4	32.1	17.3	24.0
T-Particulate P	21.7	35.0	10.9	47.0
Total P	35.4	67.1	27.5	71.0
TN/TP	22.0	10.6	27.5	14.9
Phyto. Cell Density no./ml	3980(8)	906(4)	7531(8)	496
Chlor a Turner Units	-	-	-	-
Productivity mgC/m^3/hr.	44(7)	25(5)	22(6)	5

Footnotes

Number ( ) preceeding lake name is identification used in Table 1 and Figure 1.
Number(s) following lake name are sampling stations on the specific lake.
Number ( ) following a mean value is number of samples averaged for that value if different from number at top of column.
All N and P concentrations mg/m^3.

(Continued)

APPENDIX A. SEASONAL MEAN VALUES OF LIMNOLOGICAL PARAMETERS, LAKE SAMPLES USED IN ALGAL ASSAYS Continued

Lake	(13) James		(14) Rhodhiss		(15) Hickory (16) Lookout Shoals		(17) Norman		(18) Mt. Island	
Season	Apr.-Nov.	Dec.-March	Apr.-Nov.	Dec.-March	Apr.-Nov.	Dec.-March	Apr.-Nov.	Dec.-March	Apr.-Nov.	Dec.-March
No. of Samples	6	None	5	None	9	8	15	5	12	3
Water Temp. °C	15.7	-	14.4	-	15.8	15.8	22.1	9.1	24.1	10.1
Secchi Depth-m	1.8	-	0.9	-	1.1	1.1	1.7	1.1	1.2	0.9
NH_3-N	28	-	120	-	62	51	58	37	35	28
NO_2+NO_3-N	59	-	73	-	115	114	81	309	102	320
Inorg-N	87	-	148	-	177	166	139	346	137	348
Kjel-N	205	-	350	-	296	327	215	156	231	113
Total-N	256	-	401	-	387	411	297	465	334	433
PO_4-P	6.2	-	38.6	-	7.5	7.9	5.5	5.0	6.0	5.0
T-Soluble P	7.0	-	45.0	-	12.5	13.6	6.4	6.6	6.5	6.6
T-Particulate P	12.0	-	26.7	-	25.0	24.3	3.9	7.8	5.3	6.6
Total P	17.5	-	68.7	-	38.3	38.7	10.5	14.4	12.2	13.3
TN/TP	21.4	-	10.6	-	16.6	18.6	29.5	33.1	27.6	32.6
Phyto. Cell Density no./ml	1620(3)	-	2033(2)	-	5014(4)	5678(3)	2267(13)	841	1348(9)	945
Chlor a Turner Units	20.6(3)	-	20(2)	-	28(4)	30(3)	27(13)	15	27(9)	17
Productivity $mgC/m^3/hr.$	-	-	-	-	-	-	-	-	-	-

	(19) Wylie 789, 831		(19) Wylie 681, 708, AC22		(19) Wylie SF 30		(20) Fishing Creek		(21) Wateree	
No. of Samples	7	1	9	2	3	1	3	None	11	3
Water Temp. °C	23.3	15.1	23.3	12.3	25.1	13.2	21.7	-	23.5	11.3
Secchi Depth-m	1.0	0.8	1.5	0.6	0.7	0.6	0.8	-	0.9	0.4
NH_3-N	76	140	74	85	58	180	83	-	88	220
NO_2+NO_3-N	130	395	84	390	148	420	366	-	129	441
Inorg-N	206	535	158	475	206	600	450	-	217	661
Kjel-N	250	220	267	205	380	250	500	-	419	350
Total-N	380	615	351	595	528	670	867	-	548	741
PO_4-P	13.6	30.0	8.1	22.5	23.3	50	81	-	14.8	45.0
T-Soluble P	25.1	24.0	13.2	31.0	33.6	60	120	-	25.4	70.0
T-Particulate P	6.3	31.0	7.9	34.0	44.6	45	30	-	25.6	45.0
Total P	31.4	65.0	21.1	65.0	78.3	105	135	-	48.9	115
TN/TP	13.5	9.4	16.7	9.1	6.7	6.3	6.4	-	13.4	6.9
Phyto. Cell Density no./ml	1854(6)	621	1849	341	3272	823	-	-	11,112(9)	795
Chlor a Turner Units	26(6)	9	28	15	102	15	-	-	54(9)	15
Productivity $mgC/m^3/hr.$	-	-	-	-	-	-	-	-	-	-

(Continued)

APPENDIX A. SEASONAL MEAN VALUES OF LIMNOLOGICAL PARAMETERS, LAKE SAMPLES USED IN ALGAL ASSAYS Continued

Lake	(22) Kerr Scott		(23) High Rock		(24) Tuckerton		(25) Badin	
Season	Apr.-Nov.	Dec.-March	Apr.-Nov.	Dec.-March	Apr.-Nov.	Dec.-March	Apr.-Nov.	Dec.-March
No. of Samples	3	None	3	-	3	-	2	-
Water Temp. °C	13.7	-	14.9	-	14.0	-	13.7	-
Secchi Depth-m	0.8	-	0.3	-	0.2	-	0.3	-
NH_3-N	62	-	248	-	242	-	245	-
NO_2+NO_3-N	220	-	503	-	500	-	505	-
Inorg-N	282	-	751	-	742	-	750	-
Kjel-N	200	-	343	-	470	-	345	-
Total-N	420	-	846	-	970	-	850	-
PO_4-P	5.0	-	11.0	-	5.0	-	20.0	-
T-Soluble P	21.6	-	60.0	-	38.3	-	40.0	-
T-Particulate P	25.0	-	55.0	-	81.7	-	62.5	-
Total P	46.6	-	115	-	120	-	102	-
TN/TP	9.3	-	7.4	-	8.1	-	8.8	-
Phyto. Cell Density no./ml	399	-	426	-	559	-	1929	-
Chlor a Turner Units	19	-	26.3	-	28.7	-	29.0	-
Productivity $mgC/m^3/hr.$	-	-	-	-	-	-	-	-

	(26) Tillery		(27) Blewett Falls	
No. of Samples	3	-	3	-
Water Temp. °C	15.4	-	13.5	-
Secchi Depth-m	0.3	-	0.3	-
NH_3-N	45.8	-	15.3	-
NO_2+NO_3-N	501	-	380	-
Inorg-N	546	-	395	-
Kjel-N	337	-	206	-
Total-N	838	-	670	-
PO_4-P	42.5	-	7.0	-
T-Soluble P	84.2	-	26.0	-
T-Particulate P	36.3	-	37.3	-
Total P	88.0	-	63.3	-
TN/TP	7.4	-	10.6	-
Phyto. Cell Density no./ml	1015	-	921	-
Chlor a Turner Units	21.3	-	17.6	-
Productivity $mgC/m^3/hr.$	-	-	-	-

(Continued)

APPENDIX A. SEASONAL MEAN VALUES OF LIMNOLOGICAL PARAMETERS, LAKE SAMPLES USED IN ALGAL ASSAYS Continued

Lake	John H. Kerr 19, 20, 24		John H. Kerr 2, 8, 14		John H. Kerr 118, 1308		John H. Kerr 114, 111		John H. Kerr 108, 103	
Season	Apr.-Nov.	Dec.-March	Apr.-Nov.	Dec.-March	Apr.-Nov.	Dec.-March	Apr.-Nov.	Dec.-March	Apr.-Nov.	Dec.-March
No. of Samples	8	9	8	11	5	6	5	3	7	6
Water Temp. °C	24.8	9.3	22.8	10.0	26.3	10.5	23.2	9.8	23.8	9.8
Secchi Depth-m	0.9	0.7	1.9	1.0	0.7	0.6	1.1	0.8	1.6	1.2
NH_3-N	29	65	61	62.3	54	245	57	65	34	52
NO_2+NO_3-N	139	228	66	236	88	134	23	183	45	194
Inorg-N	168	293	127	299	142	380	80	248	79	241
Kjel-N	356	224	224	237	650	1006	336	443	285	288
Total-N	495	453	290	473	738	1140	359	626	331	482
PO_4-P	6.9	17.6	7.2	9.0	24.0	51.0	7.0	6.7	7.1	6.7
T-Soluble P	14.4	30.4	16.2	23.1	36.8	80.0	7.0	11.7	9.3	13.0
T-Particulate P	21.0	38.4	3.4	15.4	71.6	103	12.4	26.7	9.4	13.7
Total P	35.4	68.9	19.6	38.4	108	191	23.4	38.3	18.7	26.7
TN/TP	15.1	8.4	14.6	13.4	7.7	6.4	15.7	16.2	19.4	21.8
Phyto. Cell Density no./ml	8904	1872	2936	2508	29653	25209	9520	11799	3426	3340
Chlor a Turner Units	43	33	23	27(6)	100	138	41	85	29	36
Productivity $mgC/m^3/hr.$	67	78	31	28(9)	109	178	47	102	33	43
	(29) Gaston		(30) Roanoke Rapids		(44) Chowan 13,17,C01,SW1		(44) Chowan MS1, RO45, AL37			
No. of Samples	1	3	None	3	16	None	9	None		
Water Temp. °C	26.0	10.8	-	10.7	25.8	-	21.4	-		
Secchi Depth-m	-	0.9	-	1.0	0.7	-	1.1	-		
NH_3-N	40	75	-	38	63	-	49	-		
NO_2+NO_3-N	20	280	-	265	137	-	81	-		
Inorg-N	60	355	-	303	200	-	130	-		
Kjel-N	390	217	-	190	677	-	465	-		
Total-N	410	497	-	455	814	-	546	-		
PO_4-P	16.0	8.3	-	5.0	15.0	-	8.3	-		
T-Soluble P	-	22.0	-	19.0	35.6	-	20.0	-		
T-Particulate P	-	11.5	-	15.0	44.4	-	22.2	-		
Total P	25.0	20.0	-	34.0	80.0	-	42.2	-		
TN/TP	16.4	18.4	-	13.4	11.4	-	13.9	-		
Phyto. Cell Density no./ml	-	5590	-	4109	3969	-	1846	-		
Chlor a Turner Units	-	29(2)	-	35	60	-	28	-		
Productivity $mgC/m^3/hr.$	-	-	-	-	-	-	-	-		

(Continued)

APPENDIX A. SEASONAL MEAN VALUES OF LIMNOLOGICAL PARAMETERS, LAKE SAMPLES USED IN ALGAL ASSAYS Continued

Lake	(31) Crystal	(32) Davies	(33) Finches	(34) Hodgins	(35) Jackson	(36) Johns	(37) Jones(JP)
Season	Dec.-March	Dec.-March	Dec.-March	Dec.-March	Dec.-March	Dec.-March	Dec.-March
No. of Samples	1	1	1	1	1	1	1
Water Temp. °C	13.1	14.4	12.7	14.5	11.5	16.1	17.1
Secchi Depth-m	0.6	0.9	1.2	0.9	0.9	1.2	0.9
NH_3-N	400	510	170	55	520	45	305
NO_2+NO_3-N	500	400	350	45	435	125	940
Inorg-N	900	910	520	100	955	170	1245
Kjel-N	550	900	340	360	950	350	530
Total-N	1050	1300	690	405	1385	475	1470
PO_4-P	250	235	15	5	50	165	5
T-Soluble P	390	240	35	18	65	195	10
T-Particulate P	20	75	15	7	60	55	10
Total P	410	315	50	25	125	250	20
TN/TP	2.5	4.1	13.8	16.2	11.1	1.9	73.5
Phyto. Cell Density no./ml	1018	1393	496	292	744	463	781
Chlor a Turner Units	56	27	24	44	24	26	31
Productivity $mgC/m^3/hr.$	-	-	-	-	-	-	-

	(38) Lytches	(39) McKensie	(40) McNeils	(41) Monroe	(42) Orton	(43) Tull
No. of Samples	1	1	1	1	1	1
Water Temp. °C	14.8	16.0	13.5	12.7	17.0	14.7
Secchi Depth-m	1.2	0.6	1.2	0.9	0.6	0.9
NH_3-N	80	30	45	40	45	55
NO_2+NO_3-N	230	40	270	25	60	195
Inorg-N	310	70	315	65	105	250
Kjel-N	280	360	640	260	270	410
Total-N	510	400	910	285	330	605
PO_4-P	30	5	20	5	5	5
T-Soluble P	45	10	35	10	10	20
T-Particulate P	5	15	35	10	20	30
Total P	50	25	70	20	30	50
TN/TP	10.2	16.0	13.0	14.2	11.0	12.1
Phyto. Cell Density no./ml	99	374	300	100	457	8815
Chlor a Turner Units	19	37	29	16	34	43
Productivity $mgC/m^3/hr.$	-	-	-	-	-	-

(Continued)

APPENDIX A. SEASONAL MEAN VALUES OF LIMNOLOGICAL PARAMETERS, LAKE SAMPLES USED IN ALGAL ASSAYS Continued

Lake	(3) Mattamuskeet		(4) Phelps		(1) Black		(2) Jones (JO)	
Season	Apr.-Nov.	Dec.-March	Apr.-Nov.	Dec.-March	Apr.-Nov.	Dec.-March	Apr.-Nov.	Dec.-March
No. of Samples	1	None	1	None	1	1	1	1
Water Temp. °C	26.1	-	25.3	-	25.3	15.0	25.0	15.2
Secchi Depth-m	0.61	-	2.13	-	0.305	0.24	1.22	0.92
NH_3-N	20	-	10	-	35	90	20	40
NO_2+NO_3-N	-	-	87	-	513	600	50	45
InSrg-N	-	-	97	-	548	690	70	85
Kjel-N	350	-	260	-	700	920	250	280
Total-N	-	-	347	-	1213	1520	300	325
PO_4-P	5	-	5	-	50	195	5	5
T-Soluble P	7	-	5	-	165	205	5	12
T-Particulate P	36	-	17	-	50	35	8	8
Total P	43	-	22	-	215	240	13	20
TN/TP	-	-	15.7	-	5.6	6.3	23.1	16.3
Phyto. Cell Density no./ml	16068	-	1279	-	1365	7944	454	2363
Chlor a Turner Units	44	-	23	-	71	80	20	27
Productivity mgC/m³/hr.	-	-	-		-	-	-	-

	(5) Salters		(6) Singletary		(7) Waccamaw		(8) White	
No. of Samples	1	1	1	1	1	1	1	1
Water Temp. °C	25.5	15.0	26.0	15.1	25.1	15.2	26.5	15.1
Secchi Depth-m	0.61	0.92	0.92	1.22	2.13	1.22	>2.74	>3.05
NH_3-N	15	35	10	50	15	45	55	30
NO_2+NO_3-N	24	10	31	40	7	10	13	15
InSrg-N	39	45	41	90	22	55	68	45
Kjel-N	350	290	250	240	380	320	150	110
Total-N	374	30	281	280	387	330	163	125
PO_4-P	5	5	5	5	5	5	7	5
T-Soluble P	11	14	10	13	5	9	30	9
T-Particulate P	6	1	14	2	12	11	-	1
Total P	17	15	24	15	17	20	13	10
TN/TP	22	20.0	11.7	18.6	22.7	16.5	12.5	12.5
Phyto. Cell Density no./ml	2333	3152	430	231	348	650	777	62
Chlor a Turner Units	27	37	36	13	29	18	13	8
Productivity mgC/m³/hr.	-	-	-	-	-	-	-	-